UNGULATE-HABITAT RELATIONSHIPS IN GIR FOREST ECOSYSTEM AND ITS MANAGEMENT IMPLICATIONS

SUMMARY

THESIS
SUBMITTED FOR THE AWARD OF THE DEGREE OF
Doctor of Philosophy
IN
Wildlife Science

BY

JAMAL A. KHAN

CENTRE OF WILDLIFE AND ORNITHOLOGY
ALIGARH MUSLIM UNIVERSITY
ALIGARH (INDIA)
1993

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INTRODUCTION

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The overall goals of the project were to understand the current status of the ungulate populations and the ecological factors influencing their distribution pattern; plus a review of the past management inputs and their impacts on the ungulate populations.

Objectives were to

(1) Describe and evaluate different habitat types.

(2) Determine ecological factors affecting their distribution pattern.

(3) Describe current numerical status of different ungulate species.

(4) Description of food habits of major ungulate species.

METHODOLOGY

To fulfil these objectives, several sets of methodology were used.

(i) **Habitat Analysis:** The vegetation was sampled along eight line transects at every 200 m using a " Ten Tree Plot" method to estimate the tree and shrub densities for different units and habitat types.

TWINSPAN and DECORANA were used to achieve objective classification and ordination of Gir vegetation. Data on tree mortality due to drought and debarking by sambar were also collected along these line transects.

(ii) Distribution and Habitat utilization: Direct sightings of ungulate species along the vehicle and foot transects and indirect evidence i.e. dung was used to indicate the habitat occupance of various ungulate species and was correlated to the various habitat parameters such topography, tree and shrub cover, water availability and grazing pressure etc.

Data were analyzed using multiple regression analysis to assess the effect of various habitat parameters on the ungulate dung density and one way analysis of variance (ANOVA) to find out the differences in the mean dung density distribution within the habitat types.

(iii) Number and density distribution : Vehicle based road transects and repeated foot transects were used to determine current wild ungulate densities. The vehicle count data were analyzed using King's, Kelker belt and Fourier series estimator whereas the foot transects data were analyzed using King's method, modified Hayne's estimator and generalised Hayne's estimator.

Area stratification (prior to sampling) was done according to different management units i.e. sanctuary west, national park and sanctuary east due to the obvious differences in vegetation and degradation factors.

A second stratification was done according to the broad topography type i.e. valleys and hills (Post facto stratification) due to the differential response of ungulates to the topography type and difficulty of achieving a random sample of the area without stratification.

(iv) **Dietary Analysis:** Direct feeding observations taken in field were summarised to find out the broad dietary pattern of major ungulate species. Weekly phenological observations of 25 food plant species and monthly grass clippings in each units were done to find out the spatio-temporal food availability of different ungulate species.

RESULTS

(i) **Habitat Aanalysis:** The eleven habitat types differed mainly in their species composition, structure and distribution in Gir. There existed significant differences in tree and shrub densities in different units and habitat types.

The tree density (>8 m) was high inside national park (301± 52.8) as compared to sanctuary west (207± 30.9) and sanctuary east (108.7± 31.8). Similar trends were observed incase of shrub class 2-6 m and 1-2 m. However the density of shrub class 0-1 m was higher in sanctuary west (1038± 322) as compared to other units .

Plant mortality also differed in different management units and was highest in sanctuary west (22.6%) and lowest in sanctuary east (16.7%). *Acacia senegal* and *Xeromphis spinosa* had the highest overall mortality.

The implications of this high mortality due to drought could be disastrous as certain species have very low regeneration in Gir. Teak (*Tectona grandis*) regeneration was high in sanctuary west and low in national park. The analysis also suggested that the teak regeneration was severely affected as the fire periodicity increased.

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6. *Anogeissus-Boswellia-Lannea* Woodland (ALBLW)

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The analysis showed that all ungulate species showed preference for certain habitat types while avoiding other.

Chital preferred TAZW, THW and TBSW whilst avoiding RW, MTW, ALBLW, ALTCW and MVC. Sambar preferred MTW, TBSW and TAZW as compared to THW, RW,ALBLW, ALTCW and MVC. Nilgai showed preference for ALBLW and ALTCW while avoiding other habitats.

The analysis also showed that the pattern of habitat utilisation of different ungulate species did not change in successive years.

The multiple regression analysis of dung data suggested that habitat parameters measured give a low predictability of the distribution of different wild ungulate species in Gir and only upto 57% of the variation in dung density was accounted by these variables.

Different habitat parameters accounted for the variation in dung density in different units. The dung density analysis also showed that chital avoided the areas heavily used by cattle as the cattle dung density was found to be negatively correlated with chital dung density, which was also found positively correlated with Ness distance

(iii) Ungulate Densities and Number: Density estimates achieved from vehicle count summer 1989, using Fourier series estimator, are discussed here to show current ungulate densities in Gir.

All four vehicle counts showed positively skewed distribution of chital group size frequencies. In such case, the mean provided a biased (over estimate) estimate of central tendency and was influenced by extreme values of data. Therefore medium group size values were used to provide unbiased estimates of current densities in Gir.

The results suggested that Gir supported a very high population of wild ungulates. Chital (*Axis axis*) was by far the most numerically dominant species in Gir (35290± 4436) followed by sambar (*Cervus unicolor*) (1038± 403), chinkara (*Gazella gazella*) (630± 288) and nilgai (*Boselaphus tragocamelus*) (605± 312). The analysis also showed that sanctuary west had more chital (21057± 3868) compared to national park (7761± 1190) and sanctuary east (9595± 1603).

The findings suggested a tremendous increase in chital population from 4,404 in 1968 and higher than estimates of chital number by forest department (10,000 in 1985). The tremendous increase in chital population resulted due to the major conservation efforts taken during the past two decades in Gir.

The chital showed a high overall density (35.0± 4.4 animals/km^2, data at 95% confidence interval) which varied in different units. The density was highest in sanctuary west (43.0 ± 7.9 animals/km^2) compared to national park (30.0± 4.6 animals/km^2) and sanctuary east (36.5±6.1 animals/km^2).

The sambar showed its maximum density inside national park (2.1± 1.0 animals/km^2) compared to other unit. The small sample size in case of nilgai only allowed calculation of an overall density estimate (0.60± 0.31 animals/km^2). The chinkara, which was mainly restricted to sanctuary east had a density of 2.4±1.1 animals/km^2.

Analysis of vehicle data according to the broad topographic units i.e. valleys and hills for chital showed significant density differences for valleys and hills. The overall chital densities in valleys and hills were 47.5± 8.5 and 21.2± 4.4 animals/km^2 respectively. Similar differences were found inside sanctuary west (35.3± 6.0 and 22.2± 6.6 animals/km^2), national park (57.9± 9.0 and 16.8± 7.6 animals/km^2) and inside sanctuary east (90.5± 19.0 and 16.8± 7.6 animals/km^2)

A very high chital density in the east for valleys was due to the repeated coverage of areas with water and may only be restricted to wetter valleys rather than whole of sanctuary east.

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The grass production was high during 1988 due to the normal monsoon in Gir. Data showed significant difference in standing crop in different unit and was high in national park (5404 kg/ha) as compared to the sanctuary west (2040 kg/ha) during October.

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February to late March, after which most of the plant species grow their per monsoon flush.

All ungulate species exhibited a mixed and generalised dietary pattern, utilising the browse and grasses in varying proportions in different seasons. Grass formed the bulk of chitals diet during all seasons whereas sambar and nilgai subsisted on browse.

A change in diet composition was observed in chital and sambar during drought. Chital mainly switched over to browse whereas sambar largely utilised bark of 9 plant species. The debarking incidences were highest in sanctuary west (13.2%) compared to national park (7.7) and sanctuary east where no barking was observed.

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Prof. A. H. MUSAVI
Chairman

CERTIFICATE

This is to certify that the dissertation **"Ungulate-Habitat relationships in Gir forest ecosystem and its management implications"** submitted for the award of Ph.D. degree in Wildlife Science, of the Aligarh Muslim University, Aligarh is the original work of **Jamal A. Khan.** This work has been done by the candidate under my supervision.

A.H. Musavi

(**A.H. MUSAVI**)
Professor & Chairman

TO PROF. A.H. MUSAVI & MY PARENTS,

WITH ALL MY LOVE.

CONTENTS

PREFACE

This thesis is the outcome of a major research programme initiated by Wildlife Institute of India in collaboration with Gujarat Forest Department in 1987 under its research project "Ungulate-Habitat Ecology in Gir". Data collected under this project on various aspects of Gir ecosystem were analyzed and summarised in the project report titled "Gir Lion Project: Ungulate-Habitat Ecology in Gir" which was submitted to Wildlife Institute of India during 1990. This thesis contains 27979 words. Chapter - 6 provides additional information on chinkara, wild boar and chowsingha densities and distribution. The data and its analysis presented in thesis is my original work and has not been submitted for any other degree from any other Institution.

ACKNOWLEDGEMENTS

I received help, support and coöperation from countless people during my stay in Gir and later during the finalization of this thesis. I, therefore, wish to place on record my sincere thanks to all those who contributed in many ways to the project and this thesis but whose names escape my memory at the time of writing this acknowledgement.

No words can express my feelings and deep gratitude for my teacher and supervisor, Prof.A.H.Musavi for introducing me to the wonders of Wildlife and later for giving me the valuable guidance throughout my career. It was indeed a great favour for which I would remain greatly indebted to him throughout my life.

I owe a lot to Mr. H.S.Panwar, Director, Wildlife Institute of India for providing me the great opportunity to work in Gir, for financial and logistic support and for his guidance throughout the project. I am also thankful to him for allowing me to use computer facilities during the preparation of this thesis at W.I.I.

My project supervisors Drs. W.A.Rodgers , A.J.T. Johnsingh and P.K.Mathur contributed to the project in various capacities. Dr.Rodgers provided vital inputs to the research methodology, data collection and its analysis. Dr.Johnsingh initially trained me in the field and Dr.P.K.Mathur looked after the administrative part of the project very well. I thank them for their help.

I also thank Mr. S.K.Mukherjee, Mr.V.B.Savarkar, Dr. Goel, Dr.P.K.Malik, Dr.V.B.Mathur and Dr. Chowdhry for their support whenever I required it. Dr.R.S.Chundawat took part in first census in Gir. I am grateful to him for that favour.

I would be failing in my endevour if I do not place on record my heartfelt gratitude to Mr.Rajesh Thapa and Mr.Sukumar for their unconditional help and valuable advice in my data analysis and preparation of thesis. This document would not have been possible without the help from Mr.Sukumar. I also thank Mr.Manoj, Mr.Navneet and Mr.Lekhnath for preparing my maps and figures.

Dr.Ajith Kumar helped me a lot in data analysis and preparing the report despite being overloaded with work at the Institute. I thank him for his cooperation. Apart from that I thank him and Mr.B.C.Chowdhury for the countless evening sessions of discussions I had with them with a glass that cheers. I thoroughly enjoyed my association with them.

My project colleague Dr.Ravi Chellam provided great help and support to my field study. I have benefitted greatly with his association. I also thank him for sharing the hardships of the project together.

I thank all my W.I.I. colleagues especially Ruchi, Bitapi, Dr. Sinha, Justus, Wesley, Shomita, Nima, for their cooperation at the Institute.

Gujarat Forest Department provided me permission to carry out my study. I wish to place on record my sincere thanks to Mr. H.A. Vaishnav, Mr. S.K. Sinha, Mr. Sanat chavan, Mr.A.K.Sharma, Mr. S.K.Pant, Mr. A.K. Saxena, Mr. Bharat Pathak, Mr. Uday Vohra and Mr. Shyamal Tikedar for their invaluable help, support and cooperation throughout my study. I also thank the entire staff of sanctuary for their excellent cooperation and support throughout my stay in Gir.

My field assistants proved indispensable for me for having an excellent jungle sense. I am greatly indebted to them for saving my life on many occasions. I thank Wazir Mohammad, Dhana Lakhman, Guga Nanji, Mohammed, Taju, Dost Mohammad, Karsan and Ibrahim for their assistance in field.

I thank Dr. Rahmani, for his valuable criticism and suggestions to me at the centre. Ms. Shahla Yasmeen collected references for my thesis, I thank her for that.

I am also thankful to my friends especially Parikshit, Salim, Qamar, Ramveer, Ainul , Azra, Partho, Raghu, Chandu for their help and support throughout the preparation of this thesis.

I have no words to express my gratitude to Aunty, Uncle,Bunty at Centre Point and Aunty, Uncle, Neeraj, Preeti at Ekta nagar for all their hospitaliteis and much needed family atmosphere during last four years.

I owe a lot to my freind Afif for providing me tremendous emotional support to get through all the trying periods during the course of my work at Aligarh.

I also owe a lot to my family members especially my parents for bearing my near total absence for many years from home. I wish someday I reciprocate for all their generosities.

Last but not the least, I thank Rashid for his unconditional help in all my endeavours at centre of wildlife. I also thank him for the stimulating discussions I have had so far with him. He not only took upon himself the task of proof reading but also provided valuable suggestions for the improvement of this thesis.

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CHAPTER - 1

INTRODUCTION

1.1 RATIONALE: The wildlife wealth of India, one of the richest and diverse in the world, has suffered considerably during the last few decades. The main factor responsible for this drastic decline in wildlife has been loss of habitat due to deforestation; for commercial exploitation and agricultural expansion as well as illegal timber poaching and domestic livestock grazing, all as a consequence of urbanisation and human population explosion, prior to enactment of Wildlife (Protection) Act in 1972. Rampant poaching even after that also took a heavy toll of wildlife. All such factors have been identified and reported by Schaller (1967), Berwick (1974), Martin (1977) and Dinerstein (1980). The effects of these factors have reduced the country's forest cover to 19.4% (Forest Survey of India,1989) in highly fragmented and degraded state. Out of the existing 19.4% forest cover, only 4.26% lies in national parks, sanctuaries and reserves with no or under coverage of several unique and biologically important biomes in different biogeographic units of India (Rodgers and Panwar, 1988). While few species such as Cheetah *(Acinonyx jubatus)* became extinct during this century, as many as, 58 species of mammals are listed as highly endangered in schedule I of Indian Wildlife (Protection) Act. Among these endangered species, 17 species have no viable populations in a national park, seven species are confined to only one protected area while there is insufficient information regarding the presence of viable populations of about five species in any national park (Rodgers and Panwar, 1988).These facts unfortunately indicate a gloomy and depressing state of wildlife conservation in India. Whatever wildlife is left now, survive inside tiny protected areas, where too their existence is threatened due to heavy biotic pressures and other problems. Outside these reserves, the survival and fate of these wildlife populations are uncertain and is not fully known.

The recent advancements in the field of island biogeography (MacArthur and Wilson, 1967) and conservation biology (Soule, 1987) have contributed much to our understanding of the effects of habitat fragmentation and isolation on the species richness, diversity and conservation of small populations. The theory suggests that reserves of at least several thousand km^2 may be required to hold on long term basis a population of about 500 effectively breeding individuals. Similarly more or less all wildlife species have a minimum threshold level below which the species becomes vulnerable to deterministic and stochastic extinction due to gradual loss of genetic variability and subsequent fitness decline of individuals (Gilpin and Soule,1986). It is, therefore, apparent that with limited understanding of ecological processes in the Indian context, the conservation of wildlife poses a serious challenge to planners and requires considerable research and managerial skills.

Interest in natural history (Blanford, 1888 - 91; Brander, 1923; Pocock, 1939) and wildlife conservation is quite old in India (Ali, 1927 & 1953; Rao, 1957). However scientific research on wildlife has lagged behind that of in other regions such as East Africa and North America. Growing awareness and realisation by managers of the fact that casual approach towards wildlife conservation can only be counterproductive and may do more harm than good, is leading to increased appreciation of research in formulation of long term management strategies for protected areas. There is an urgent need to upgrade our knowledge of status, distribution and life history of different wildlife species as also of management oriented research in protected areas. Such have been the motivation for taking up of the present study which deals with several aspects of the highly endangered Gir ecosystem which has a unique biological community and is the last refuge of the Asiatic lion (*Panthera leo persica*).

The Asiatic lion had a distribution range extending from Greece through Iran, Iraq, Afghanistan, the present Pakistan to India (Joslin, 1973). In the Indian subcontinent, lion was found throughout western and much of the north and central parts with the Narmada as the southern limit of the range. But since 1880, the species is merely confined to Gir forest in Gujarat state of India. Thus the Asiatic lion provides a sad example of a wildlife species being pushed out of its former range into a narrow habitat barely sufficient for its safe survival.

At the turn of this century, Gir forest covered an area of 3107 km^2 (Joshi,1976) which has shrunk to its present size due to clearance of forest for agricultural and commercial purposes to meet the requirements of a fast growing human population around it. Apart from this, throughout Gir forest, Maldharis (a traditional pastoral community) graze their domestic livestock. To protect the native fauna and flora, Gir forest was declared a sanctuary in 1965. No specific attention was paid to the Asiatic lion before 1965. The conservationist realised the complexity of the situation only when during sixties and seventies concerted research by Hodd (1969), Joslin (1973) and Berwick (1974) assessed the impact of local maldharis on the Gir ecosystem. Intensive grazing by domestic cattle and other activities of maldharis had been degrading the lions habitat in terms of soil erosion, retarded growth of vegetation and declining population of wild ungulates. As a consequence of all these factors, lions were compelled to prey on domestic livestock whose population had been in excess of the carrying capacity of the habitat. It was found that approximately 75% of lion's food consisted of domestic livestock (Joslin, 1973).

These major research findings led to the Gujarat Forest Department taking several conservation measures such as shifting of a number of pastoral settlements outside Gir, creation of a national park of 258 km^2 within the sanctuary, water hole development, exclusion of migratory livestock and more effective steps for protection. Unfortunately no follow up was done to evaluate the results of these measures in Gir.The Wildlife Institute of India, in collaboration with Gujarat Forest Department, started the "Gir Lion Project" in 1986 to evaluate the past management inputs and to study the current condition of prey and predator species. The project further aimed at gathering crucial information about Gir ecosystem and to incorporate the findings into better management of Gir Lion Sanctuary and National Park. The project had two components; one dealing with the Asiatic lion and their current predation and ranging patterns and the other dealing with ungulate populations and the ecological factors affecting their distributions. This thesis summarises the findings of the work done under Ungulate-Habitat Component of the project.

1.2 OBJECTIVES: The broad objectives of this study were:

1. To describe and evaluate the different habitat types in Gir.
2. To investigate the distribution pattern of major ungulate species with respect to different habitat parameters.
3. To estimate the numbers, densities and distribution of different ungulate species in Gir.
4. To investigate the dietary pattern of major ungulate species in relation to spatio-temporal availability of food.

1.3 DURATION OF STUDY: The field work for this study was started in February 1987 and was continued till May 1989. In total, 28 months were spent in Gir for data collection.

1.4 ORGANISATION OF THE THESIS: There are eight chapters in this thesis. The chapter IV,V,VI and VII have three sections i.e.introduction, results and discussions. In these chapters details of data collected and its analysis are also provided.

- Chapter I is general introduction.
- Chapter II introduces Gir Lion Sanctuary, its area and management. It also reviews the research carried out so far in Gir and its management inputs.
- Chapter III has a detailed account of the methodology adopted for data collection and its scientific basis.
- Chapter IV deals with the vegetation of Gir. It provides details of habitat classification, species composition, regeneration and species specific mortality due to severe drought in various management units of Gir.
- Chapter V deals with habitat utilization pattern of different ungulate species.
- Chapter VI deals with ungulate species and their densities. It summarises the results of four vehicle censuses and line transect studies.
- Chapter VII contains details of the food habits of major ungulate species based on the direct observations. A summary of the data collected on plant phenology and grass production has also been given in this chapter.
- Chapter VIII deals with the management implications of the present study.

CHAPTER - 2

STUDY AREA : GIR LION SANCTUARY & NATIONAL PARK

2.1 HISTORY: Prior to 1947, Gir forest was part of Junagarh and Baroda estate. In 1877 Gir forest covered 3,107 km^2 (Joshi,1976). Uncontrolled commercial exploitation of forest and expansion of human settlements over the years reduced it to its present size. Exploitation of forest for profit took precedence over wildlife conservation. It was not until 1920 that a small portion of Gir forest (Devalia block) was declared as a sanctuary for lions. The vegetation of Gir has undergone considerable changes during last several decades due to management practices in vogue mainly for teak, excessive grazing and recurrent fires. The former ruler of Junagarh fortunately realised the need to protect the endangered lion and banned hunting with considerable success. The lion population which fell to as low as 15 animals at the turn of century, increased to 285 (Chellam, 1993). Gir forest was raised to the status of a sanctuary in 1965 and later in 1974, 258 km^2 area of the sanctuary was declared as a national park.

2.2 LOCATION AND SIZE : Gir Lion Sanctuary and National Park (Figure 1) lies 40 km from the coast in the Kathiawar peninsula of Gujarat (20° 57' to 21° 20' N latitude and 70° 27' to 71° 13' E longitude). At present Gir sanctuary covers an area of 1412.13 km^2 , which includes an area of 258.71 km^2 of the national park. It reaches its maximum length of 80 km along the East-west axis and is 16-24 km in width. The sanctuary is narrowest at the east and west ends. Three different management units can be recognized in Gir. They are sanctuary west, national park and sanctuary east. These units differ in terms of their vegetation, topography, rainfall inputs and degradation.

2.3 TOPOGRAPHY: Gir forest is hilly and undulating hills extend one after the other in different directions. The altitude ranges from 152 m in western part of Gir to 648 m at Sarkala hill near Chachai Pania. The Gir hills drop off to flat and valley areas. Small streams cris- cross the entire Gir which in turn join major rivers. Gir forms the major catchment for 9 rivers of which four rivers have been dammed. The rivers are Hiran, Shingavada, Machundri, Raval, Malan, Dhataradi, shetrungi and Popatadi.

2.4 GEOLOGY AND SOIL : The general formation of Gir hills consist of traps (Basalt) of varying composition associated with granite and gneiss overlain by beds of calcareous sandstone which in part assumes the nature of limestone (Santapau and Raizada, 1956). The soil is mainly laterite with patches of Black cotton soil in low lying areas. Soil texture varies greatly from gravelly sand along river banks to the black cotton clayey.

Water holding capacity is the lowest in sandy loam and highest in black clay which remains water logged during monsoon. Soil layer thickness varies in different areas and is up to 1 m thick in valley areas.

2.5 CLIMATE : The climate of Gir is generally hot with an erratic monsoon. Seasons in Gir are fairly distinct. June through September is the monsoon, followed by a post monsoon season. Late November to early March is the cool season. This is followed by a hot dry season from mid-March to mid-June. The temperature drops to less than 10 °c in winter and rises to 43 °c (Figure 2) during the hot dry season. In Gir, the monsoon is unpredictable and every fourth or fifth year is a drought year. The South-west monsoon normally arrives in Gir around mid-June and 80% of the annual rainfall is received during the next two months.

There is a climatic gradient on a west to east axis. Data from Kamleshwar Dam in Gir west for the past 28 years and Raval Dam in extreme south east for past 11 years show the average rainfall to be approximately 1,012 mm and 632 mm respectively. 1987 was a drought year when Gir received only 327 mm rainfall (Figure 3).

2.6 VEGETATION : Gir vegetation is quite homogenous. Nearly 70% of Gir is dominated by teak (*Tectona grandis*) and its several associations. However there is wide variation in the species composition. The appearance of the vegetation in west is of a forest. The remaining 30% of Gir is covered by thorn forest interspersed with patches of dry deciduous forest, thorn bushland, savannah and degraded scrub savannah.

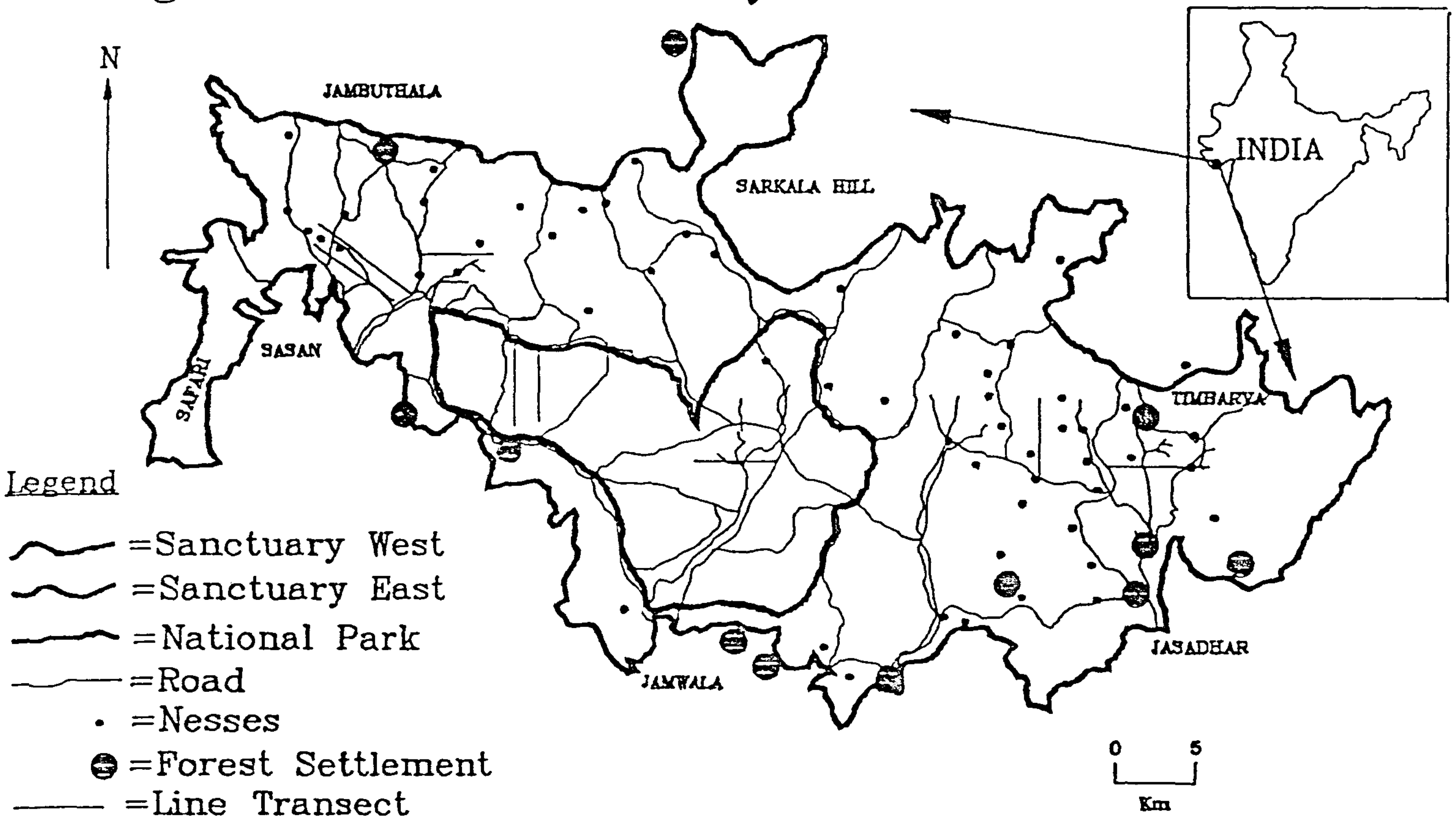
The vegetation changes along the west to east axis. In eastern portion, teak is replaced by *Anogeissus latifolia* which is mainly a result of the increasing aridity gradient along the west to east axis. Eleven broad habitat types which differ mainly in their species composition and distribution can be recognised in Gir.

2.7 FAUNA : Gir has quite a diverse fauna as compared to other protected areas. More than 24 species of mammals and 250 species of birds are found in Gir. No authentic or published information is available on reptiles, fish, amphibians and invertebrates.

2.8 MALDHARIS: Small settlements (locally known as Nesses) are occupied by maldharis throughout Gir. They are mostly pastoral in their occupation. Though there is no authentic record of precisely when maldharis arrived in Gir, they are there probably for the last 150 years. At present there are about 2,200 Maldharis living in 74 nesses with a livestock population of about 14,000.

2.9 PAST RESEARCH INPUTS : Preliminary work in Gir forest included surveys and lion censuses (Wynter-Blyth and Dharmakumarsinhji, 1950; Dharmakumarsinhji & Wynter-Blyth, 1951; Wynter-Blyth, 1952 and 1956). These censuses were the earliest attempts to estimate the lion population in Gir. Santapau and Raizada (1954 & 1956) conducted surveys in Gir and provided an inventory of flora. During the late sixties three independent research projects were started; Hodd (1969) worked on the impact of Maldhari grazier on vegetation, Joslin (1973) on the ecology of Asiatic lion and Berwick (1974) on the ungulate community of Gir forest.Rio (1983) and Habibullah (1984) have done work on the phytosociology and productivity of some of the tree species in Gir. Sinha (1987) undertook a study of the ecology of wildlife in Gir and provided information on predation pattern of lion. During the past two decades there have been many publications (reports, papers etc.) by different officers of Gujarat Forest Department on Gir as well as lions.

Fig.1 Gir Lion Sanctuary and National Park



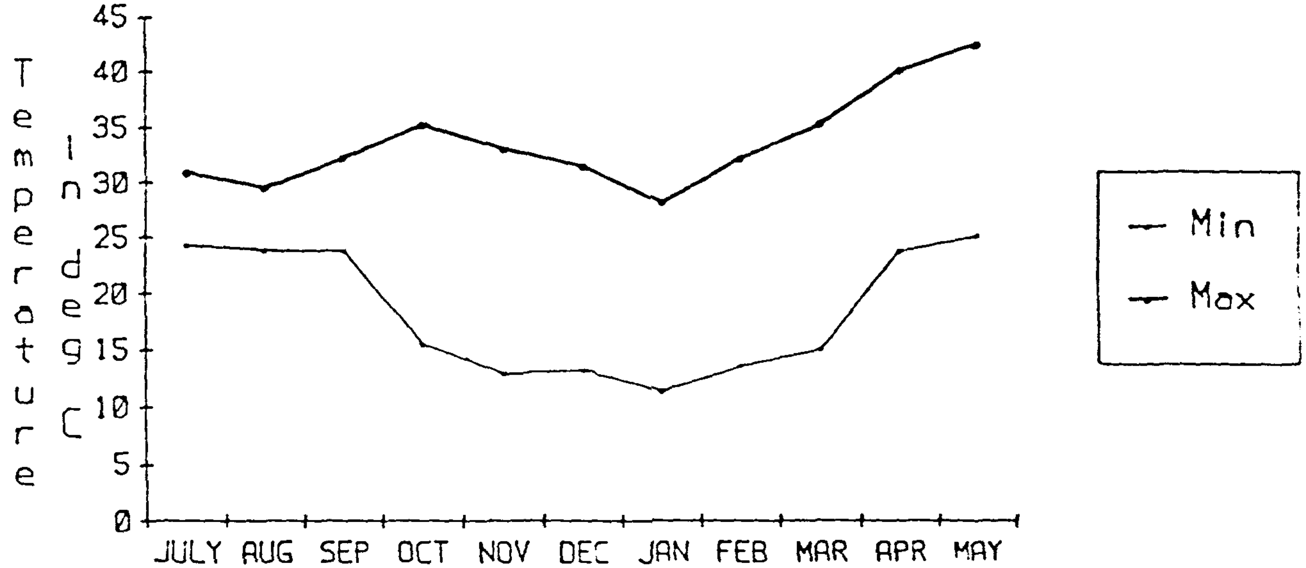


Fig.2 Minimum and Maximum mean values of temperature for various months in Sasan from July '87 to May '88.

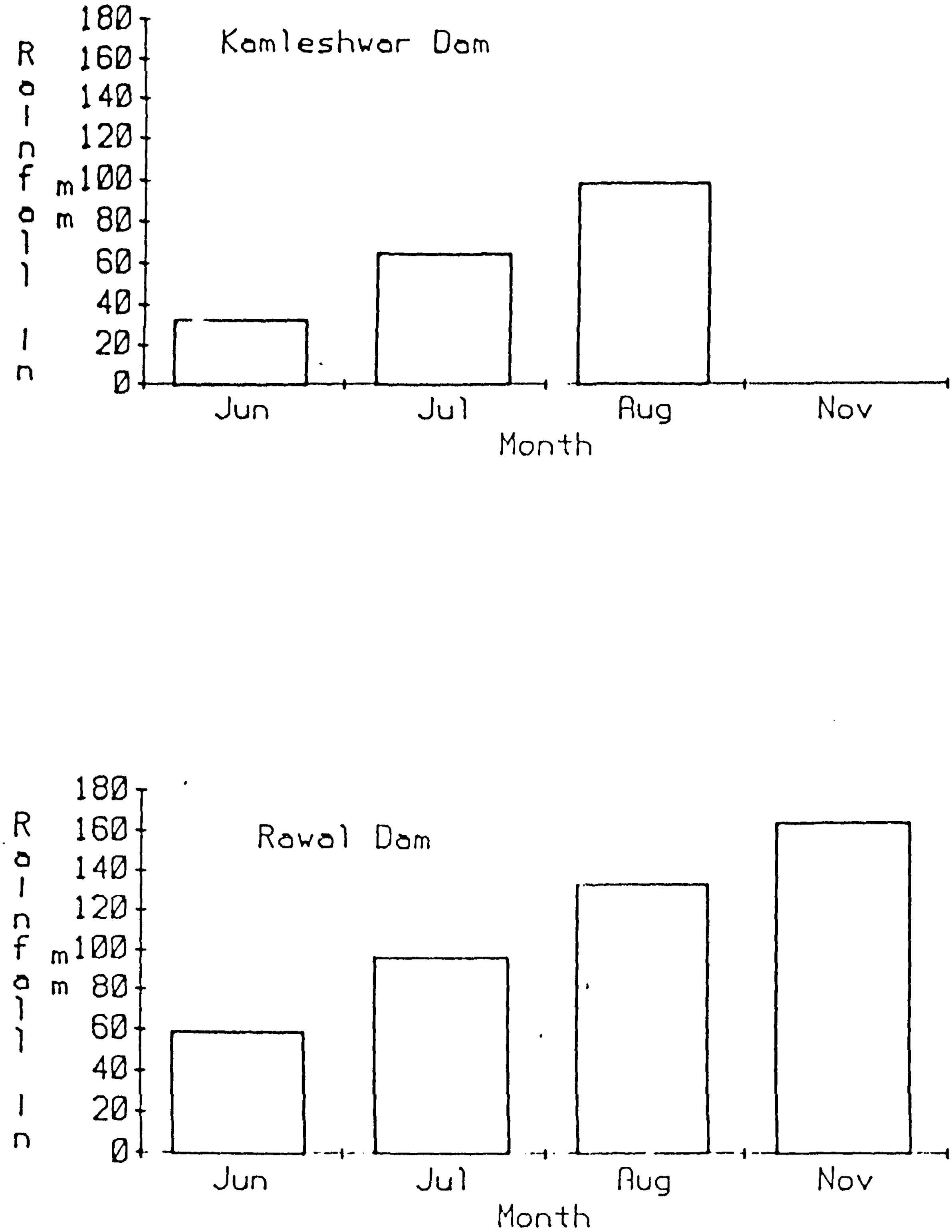
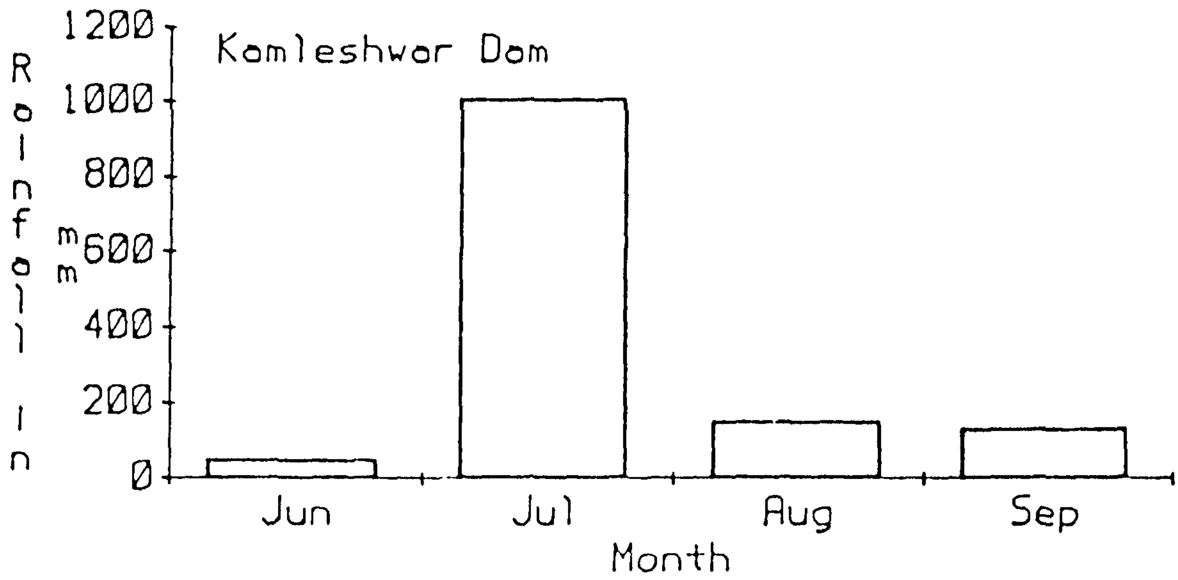


Fig.3 Amount of rainfall received in 1987 in Gir (West) and Gir (East).



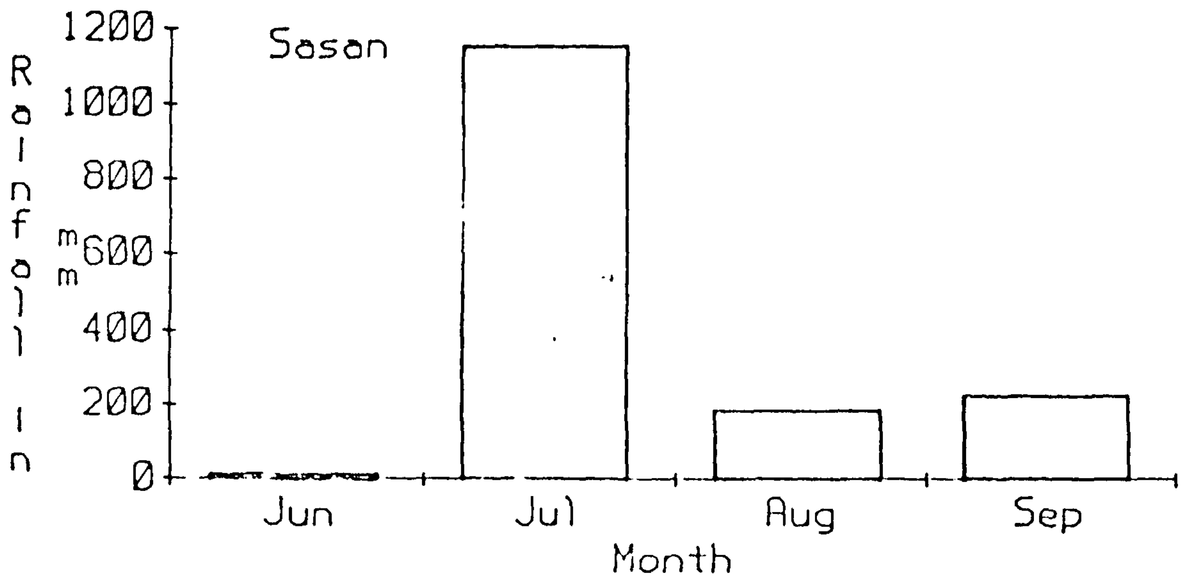
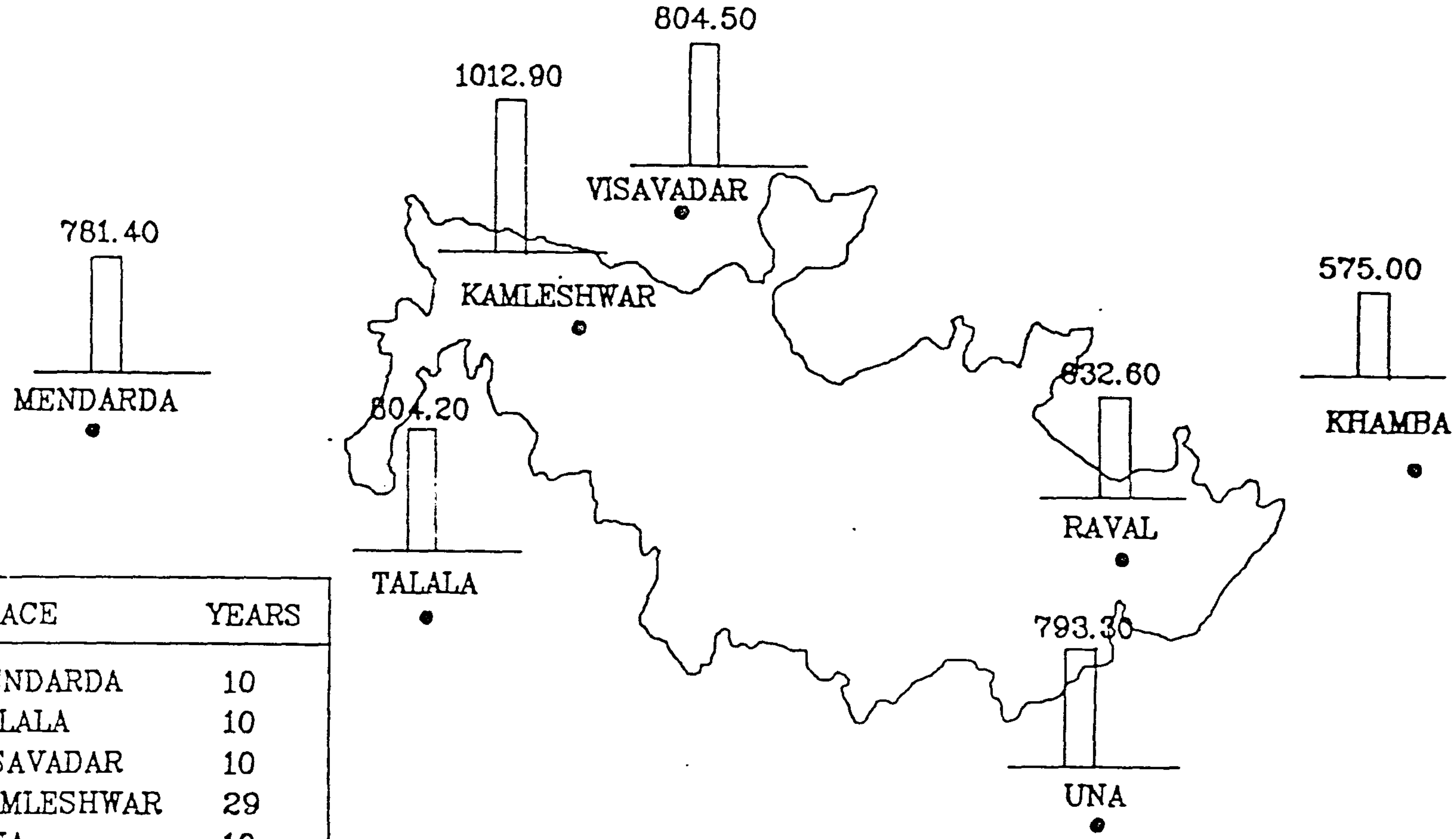


Fig.4 Amount of rainfall received in 1988 in Gir (West).

Fig.5 Mean Rainfall Pattern at Different Places in and Around the Gir Lion Sanctuary



PLACE	YEARS
MENDARDA	10
TALALA	10
VISAVADAR	10
KAMLESHWAR	29
UNA	10
RAVAL	11
KHAMBA	2

CHAPTER - 3

METHODOLOGY

3.1 HABITAT ANALYSIS: Data on plant species composition in various habitat types were collected along the eight line transects using "Ten Tree Plot" method. The vegetation was classified into the following height categories:

1) <1 m   2) 1-2 m   3) 2-6 m   4) >6 m

Ten trees (>6 m) and ten shrub species (2-6 m) nearest to every sampling point were recorded. The distance between 10th and 11th tree was also recorded. This was repeated for the shrub class 2-6 m. The shrub categories 1-2 m and 0-1 m were counted in the 10 m radius circular plots. For each individual tree and shrub species following data were also recorded:

a) Girth at breast height

b) Status (Dead/Alive)

c) Debarking in three subjective categories

1 = Slight (<1/4 of bark circumference removed)

2 = Medium (1/4 to 1/2 bark circumference removed)

3 = Heavy (>1/2 bark circumference removed)

The other data recorded were:

1) Topography/Slope

2) Vegetation type

3) Dominant grasses

4) Fire (history, extent)

5) Grazing pressure 0 = None, 1 = some, 2 = Medium, 3 = Heavy

6) Lopping pressure 0 = None, 1 = Some, 2 = Medium, 3 = Heavy

Tree and shrub density were calculated using the following formula:

$$D = \frac{n}{r^2} \times 10,000$$

Where n = Number of trees sampled

D = Density

r = Radius

Radius was calculated by summing up the distance between 10th and 11th tree and dividing it by 2.

3.2 HABITAT UTILISATION: The habitat utilisation patterns of different ungulate species were quantified by two methods.

3.2.1 Direct method : Direct method involved sampling the various habitat types and recording the sightings of individual animal species along both line and road transects. All ungulate sightings have been described as follows:

	Variables	Categories
1.	Segment	Km or line transect segment
2.	Topography	0=Dam, 1=Plateau, 2=Hills, 3=Dissected, 4=Valley, 5=Plain
3.	Slope	1=Flat, 2=Gentle, 3=Steep
4.	Three dominant tree species	
5.	Three dominant shrub species	
6.	Tree cover	1=None, 2=Open, 3=Medium, 4=Dense, 5=Closed

7.	Shrub cover	1=None, 2=Open, 3=Medium, 4=Dense, 5=Closed
8.	Grass cover	0=Absent, 1=Tiny, 2=<.5 m 3=>.5 m poor, 4=>.5 m good, 5=>1 m
9.	Rock	1=Absent, 2=Few, 3=Many
10.	Grass colour	1=Brown, 2=Yellow-Brown, 3=Yellow, 4=Yellow-Green, 5=Green
11.	Litter	1=Absent, 2=Scarce, 3=Moderate, 4=Abundant.
12.	Lopping evidences	1=None, 2=Few, 3=Many
13.	Cutting evidences	1=None,2=Few, 3=Many
14.	Grazing evidences	1=None, 2=Few, 3=Many
15.	Distance from Ness	Measured from toposheet
16.	Distance from water	Measured from toposheet
17.	Escape cover	Measured in 5 m classes.

3.2.2 <u>Indirect method</u>: Dung is a reliable indicator of animal presence and has been made the basis of evaluation of habitat utilisation extensively by various workers on ungulates (Eisenberg & Lockhart, 1972; Berwick, 1974; Dinerstein, 1980). Four transects, each of 30 m in lengths were placed at every 200 m distance on each line transect. Pellet groups seen within 1 m on either side of the 30 m long transect were counted. Dung pellets of different herbivore species were identified on the basis of shape, colour and spread. In case of nilgai, chowsingha and chinkara, the whole dung pile was treated as one rather than counting the pellet groups of the concerned species. The dung sampling was done once in winter 1988 and repeated in the winter 1989.

Ground and shrub cover values along 30 m transects were quantified by Two Step Method (Riney, 1952). The toe of the right shoe was marked and 50 steps were walked along each transect. At every second step the ground cover category that hit the mark was recorded. The presence/absence of shrub cover category was also recorded. The ground cover categories sampled were:

1. Bare soil
2. Rock
3. Dung
4. Grass
5. Herb
6. Litter

The shrub categories recorded were :

1. Shrub cover 1 0 - 1 m
2. Shrub cover 2 1 - 2 m
3. Shrub cover 3 2 - 3 m
4. Shrub cover 4 > 3 m

3.3 UNGULATE DENSITIES AND NUMBER : The following two methods were employed for estimation of herbivore population in Gir.

3.3.1 Road transects:

Methodology for estimation of herbivore populations was decided keeping in view the open habitat of Gir criss crossed by a network of roads and good chances of animal sightings. The animals were counted while driving at an average speed of

20 km/hr. Four censuses were conducted throughout Gir during summer and winter of 1987, 1988 and 1989. No such census was possible during monsoon and post-monsoon season.

The first census was conducted in summer of 1987 to get an idea of ungulate densities in sanctuary west and national park whereas during the second census more attention was paid to overall density distribution of different ungulate species. During the third census operation, more emphasis was paid to the intensive monitoring of certain road transects. Two road transects were selected in each management unit of Gir with a view to standardise the methodology and the variability in animal sightings and to correlate the animal sightings with habitat factors.

Road transects were marked in advance on a map and were monitored between 0600 hours to 0900 hours and 1700 hours to 1930 hours. An open jeep with a crew of five people was used for the census.

For each animal sighting following data were recorded:

1) Species, number, age and sex.
2) Perpendicular distance from the centre of the animal group to the edge of the road.
3) Major habitat parameters such as broad habitat types, terrain rockiness and grass cover.
4) Major activity of the group.

Grouping of perpendicular distance into categories does not affect the density estimation (Burnham *et al.*, 1980). The perpendicular distance (measured in terms of five m classes), from the centre of the animal group to the edge of the road was visually estimated. These visual estimates were occasionally checked by measuring through steps.

Road transect data were analyzed using three methods:

a) King census method

b) Kelker belt transect method

c) Fourier series analysis

a) King census method: This is perhaps the oldest method developed to analyses census data based on an estimation of the effective strip width. Its utility in Indian conditions cannot be denied as other sophisticated methods necessarily require the help of computer. The method is quite reliable and provides consistent results. Mean perpendicular distance (M.P.D.) was calculated using the formula:

$$\text{M.P.D.} = \frac{\text{Sum of all average class interval x all animal sighting frequency in each class}}{\text{Total number of animal groups seen}}$$

A mean M.P.D. value was calculated for each species of ungulate. M.P.D. for different units of Gir i.e. sanctuary west national park and sanctuary east were calculated where the data set were sufficient to produce a reliable figure.

Density was estimated using the following formula:

$$D = \frac{n}{2L \times Fy}$$

Where N = Total no. of animals of each species seen

L = Length of the transect

Y = Mean perpendicular distance

F = Correction factor

F is a function of vegetation and modifies the density estimates. It varies from 1 in dense woodland to 2 in very open forest. The value used for Gir was 1.5 due to its open habitat conditions. Confidence limits were derived by calculating separate M.P.D. for each individual transect and thus calculating the mean density estimate. The formula for calculating the confidence limit is as follows:

$$\text{Confidence limit} = \frac{\text{Standard deviation}}{n} \times 1.96$$

b) Kelker belt transect method: The animal sighting frequency data are plotted against the distance classes. The distance class at which group sighting frequency starts dropping off is treated as the effective strip width. All animal sightings beyond this effective strip width are rejected and density is calculated by using the following formula:

$$D = \frac{n^{o} - ESW}{2L \times ESW}$$

Confidence limits were calculated from individual transect densities using overall effective strip widths. With large data sets, separate effective strip widths were calculated for different units.

c) Fourier series method: The method is based on the Fourier series expansion of probability density function over the limit interval 0 to W (W being the largest perpendicular distance). The fourier series estimator is model robust, pooling robust and satisfies the shape criteria $F_{(0)} = 0$ (Burnham *et al.*, 1980).

Density for given set of census data can be expressed as follows:

$$D = \frac{n\,F_{(0)}}{2L}$$

Where n = Total number of animal groups seen, L = Length of transect

$F_{(0)}$ = Probability density function.

For a set of data with known values of n and L the only unknown parameter needed for density estimation is $F_{(0)}$.

Analysis of grouped data : Estimation of $F_{(0)}$ for grouped data by fourier series method is as follows:

$$F_{(0)} = \frac{1}{W} + \quad a_k$$

In this equation when 'W' is specified (either the maximum perpendicular distance or a specified value in case of truncated data). Data truncation involves rejection of extreme values of animal sighting from the analysis. 'a_k' is the unknown parameter needed to be estimated after selection of required number of 'm' terms. The number of terms required to estimate the best fit for F.S. model of P.D.F. can be achieved either by log likelihood ratio or by Chi-square goodness of fit test (Burnham *et al.*,1980).

Species wise distribution maps of animals were prepared on the basis of sightings. The roads were divided into one kilometre segment by the help of the vehicles mileometer readings Animal sightings were marked on these segments. Grids of 5 x 5 km were marked on the map of the area. The total number of animals were divided by total number of road segments in a grid. These grids were categorized as high, medium and low in accordance with the estimated abundance.

3.3.2 Line transect studies : Line transects were permanently marked in the field and were traversed by walking along them. Animals seen on either side were counted. The following basic assumptions are made in line transect studies (Burnham *et al.*, 1980).

1. Animals are randomly distributed in the area.
2. Animals directly on the line will never be missed.
3. Animals are fixed at the initial sighting position and do not move before being counted.
4. Distances and angles are accurately measured.
5. Sightings are independent events.

As the ungulates in Gir tend to aggregate around water sources, the first assumption appears to be wrong. However, by the random placement of lines in different areas the violation of the assumption has been prevented. There are very little chances of violating the other four assumptions in Gir where open habitat conditions permit easy detection and accurate measurements. Eight line transects each of six km were randomly marked on permanent basis and numbered, in three units of Gir. There were three transects in sanctuary west, three in national park and two in sanctuary east. Thirty sampling points were located, 200 m apart, on each transect. Census was conducted along transects only in the morning hours. For each sighting, the following data were recorded.

1. Sighting angle to the centre of the group.
2. Straight line distance i.e. the distance of the observer from the point on the transect perpendicular to the location of the animals.
3. Sampling point number.

The data were analyzed by following methods:

a) Haynes estimator

b) Modified Haynes estimator

c) Generalised Haynes estimator

d) King census method

The basic assumption for the Haynes estimator is that mean sighting angle should be 32.7°. Failure to this assumption implies that the sin 0 is a uniform random variable on (0,1). The Haynes estimator is not robust enough to this failure of its basic assumption. In case the mean sighting angle exceeds 32.7° and lies between 32.7 and 45° then the modified Haynes estimator is to be used. When it is significantly greater than 45° or less than 32.7° the generalised Haynes estimator is to be used.

a) **King census method**: The angular sighting distance (A.S.D.) is calculated as follows:

$$\text{A.S.D.} = \frac{\text{Straight line distance}}{\text{Cos}(0)}$$

and the density is calculated using the following formula:

$$D = \frac{n}{2L \times Y}$$

Where n = Total number of animals seen

L = Length of the transect

Y = Mean angular sighting distance

The confidence limits were calculated by estimating the mean density from individual transects for each transect and species.

3.4 DIETARY ANALYSIS : Data on dietary spectrum, grass/browse ratio, food preference and spatio-temporal food availability were collected by the following method :

3.4.1 Direct observations : Observations were made wherever animals were seen feeding. However, this method proved difficult due to large flight distances of ungulates. Browsing on each plant species and on different parts of plants were recorded wherever observed mostly while driving. Observations on sambar were not possible during monsoon and post monsoon season as they remained mostly under dense cover on higher hills.

3.4.2 Phenological studies : Phenological study plots were maintained in sanctuary west near Kankai barrier in 1987 and near Valadara area during 1988. The primary objective of phenological studies was to find out the seasonal availability of different plant parts to the ungulates.Twenty five trees and shrub species (one individual of each species) were marked at Kankai barrier plot which are consumed by ungulates in Gir. Weekly observations were made on the following growth stages of each plant species:

a) Leaf less

b) Leaf emergence

c) Mature leaf

d) Flowering

e) Fruiting

f) Leaf fall

Simultaneous presence of two different stages of a species was also recorded. Twenty species of plants were studies in 1988. Five individuals of each species were marked to find out the variation within a species in regard to different phenological stages. Three years of severe drought in Gir caused extensive mortality in some plant species. Marked trees which died due to drought were excluded from the observations and fresh specimen were marked for further observations.

3.4.3 Biomass estimation : Standing crop of grass varies greatly from one area to another depending upon differential rainfall and grazing pressure. Grasses were clipped in selected plots in sanctuary west and national park. Grasses and herbs were clipped to the group level in ten 50 cm^2 and five 1 m^2 quadrates. Clipping was done every month with the onset of monsoon to the beginning of winter season during 1987 and 1988. The two major habitat types (Teak dominated hills and *Acacia* dominated valleys) were studied in 1987, whereas a comparison was made between two units, i.e. sanctuary west and national park in 1988. Two levels of grazing were recognised in both the units.

a) Sanctuary west (Highly grazed and moderately grazed)

b) National Park (Moderately grazed and not grazed)

Two sets of five 1 m^2 size quadrates were clipped at each site every month. Clipped samples were oven dried at 80 $_{o}$c for 24 hours and weighed.

CHAPTER - 4

HABITAT DESCRIPTION AND ANALYSIS

4.1 INTRODUCTION : As the animal populations are directly or indirectly dependent on vegetation, a scientific analysis and monitoring of vegetation in wildlife habitats forms an essential component of management. The success of habitat oriented management of Serengeti and other East African wildlife reserves has indicated the importance of long term vegetation monitoring. It has been seen that such long term studies and monitoring helps in correlating fluctuations in animals populations to biotic and abiotic factors and in simulation of ecological models. But unfortunately in India, wildlife management has been largely species oriented, ignoring the vegetation and other ecological factors. This has sometimes resulted in failures because changes in the quality and character of habitats significantly affects fauna. A systematic study of vegetation and other components of the ecosystem is therefore necessary for the achievement of desired conservation goals.

The vegetation of Gir, though simple, has been greatly modified due to past biotic interference (Berwick, 1974). Among several factors, grazing by domestic livestock, fire and unpredictability of monsoon have played significant roles in altering the vegetation. Had there been proper monitoring of vegetation in the past, it would have been much easier to foresee the likely changes in the future in vegetation and their impacts on animal populations.

This chapter describes the work done on the Gir vegetation. The various aspects of vegetation such as community classification, species composition, succession and mortality in plant population etc. have been described.

4.2 DATA COLLECTION : The vegetation was sampled on eight randomly placed line transects totalling 48 km. There were three transects in sanctuary west, three in the national park and two in the sanctuary east. The vegetation was stratified in four height categories and was quantified at fixed interval of 200 m on the line transects using Ten Tree Plot method. The variables thus measured have already been described in methodology.

4.3 DATA ANALYSIS: The vegetation of Gir was classified on the basis of major tree species in the upper storey by using computer programme TWINSPAN (Two way Indicator Species Analysis) developed by Hill(1979a). The 'Ten Tree Plot' data was converted into species by sample matrix having number of species on Y-axis and the samples on x-axis. The programme utilised divisive polythetic classification strategy to construct an ordered two way table of samples as well as species. The vegetation ordination was done by using computer programme DECORANA (Detrended Correspondence Analysis) also developed by Hill (1979b).

Tree and shrub species densities were calculated for each sample and were added together to get the mean density estimates for each unit, height category and confidence intervals. These density values were compared statistically to find out the significant differences between the units. Plant species diversity was calculated by Shanon- Wiener function (Krebs, 1972; Greig-Smith, 1983) for each height category and management unit.

Data on plant mortality were summed up for different girth classes, units and percentage mortality calculated. The Bonferroni confidence intervals were constructed following Neu *et al.* (1974) and Byers *et al.* (1984) to detect the significant differences in species specific as well as girth class mortality.

4.4. RESULTS

4.4.1 Habitat classification: The results of habitat classification have been summarised in Table 1.

Eleven broad habitat types have been subjectively recognised in Gir. The table also provides information on the distribution (topographic and coverage at the level of different management units) of these habitat types and the characteristic tree species in upper and middle storey.

The vegetation classification done through computer programme TWINSPAN is given in Figure 6 and Figure 7 for sanctuary west and sanctuary east respectively. In sanctuary west 180 samples having 45 plant species were subjected to TWINSPAN analysis. In total four homogenous groups of plant species responding to different set of ecological conditions were distinguished by the help of computer programme. At the first dichotomy, there were 39 plant species in negative group and 6 species in positive group. The positive group consisted of evergreen species (e.g. *Syzygium rubicundum, Pongamia pinnata, Manilkara hexandra*) confined to riverine forest. Further divisions of this group were undesirable and meaningless considering the fact that these species belong to unique vegetation type and have restricted distribution along the river courses. The negative group of 39 species splitted in three homogenous groups after several levels of dichotomies at lower hierarchy. The first group consisting of *Tectona grandis* as dominant and *Acacia nilotica, Acacia senegal* and *Zizyphus mauritiana* as co-dominants, is distributed on flat areas of sanctuary west having deep clayey soils. At several places where clear felling has taken place (e.g. water reservoirs) or patches of Black cotton soils exist, pure stands of *Acacia nilotica, Acacia senegal* and *Zizyphus mauritiana* are found.

The second group contains plant species (e.g. *Pterocarpus marsupium, Cassia fistula, Holarrhena antidysenterica*) which are distributed in moist valleys of west Gir. The third group contains the species which are found on hills preferring rocky terrain and gravelly soils adapted to dry regimen. The characteristic tree species include *Boswellia serrata, Lannea coromandelica, Acacia catechu* and *Sterculia urens, Syzygium rubicundum* and *Acacia senegal* were fine differential species preferring right and left sides of primary dichotomy. However large number of plant species behaved indifferently (e.g. *Tectona grandis, Acacia catechu, Wrightia tinctoria*) to the primary axis due to their wide occurrence across the sanctuary west. In sanctuary east, the programme recognised two broad groups of plant assemblages. The first group having *Anogeissus latifolia* as dominant tree species and *Acacia nilotica, Zizyphus mauritiana, Diospyros melanoxylon* and *Wrightia tinctoria* as codominants, are distributed on flat and undulating rocky terrain. Patches of Black cotton soils support thorn woodland and lack *Anogeissus latifolia* in top storey. The plant species of second group are largely distributed on hills. The distinction between differential and anomalous plant species in sanctuary east was much more obvious than in sanctuary west. There were six plant species preferring left side of the primary dichotomy and an equal number of species preferring right side of the axis. *Acacia senegal* and *Boswellia serrata* were two fine differential species indicating distinct ecological preferences.

4.4.2 Ordination: The sample species matrix having 212 samples and 57 plant species was subjected to ordination analysis using computer programme DECORANA. The distribution of all the plant species was examined on various axis. All the plant species showed meaningful distribution on the second and third axis (Figure 8). The maximum spread of plant species was observed along the third axis and to some extent also along the second axis. The spread of plant species along the third axis suggests that topography is largely controlling the distribution of plant species as riverine elements (*Syzygium rubicundum, Pongamia pinnata, Manilkara hexandra*) which are confined to river valleys only, occupied one extreme of the third axis and species confined to hill tops (*Soymida febrifuga, Boswellia serrata, Lannea coromandelica, Terminalia crenulata* and *Sterculia urens*) occupied the other extreme of the third axis. Plant species such as *Tectona grandis, Acacia catechu, Cassia fistula, Holarrhena antidysenterica* and several others occupied intermediate position along the third axis suggesting their wide distribution in Gir on a variety of topography types. The spread of plant species along second axis suggests some influence of soil moisture too on plant species distribution as *Acacia nilotica* and *Acacia senegal* occupied one extreme of the second axis while all riverine species occupied the other extreme of the second axis. Plant species such as *Bombax ceiba, Zizyphus mauritiana, Zizyphus xylopyrus* and *Xeromphis uliginosa* occupied intermediate position on the second axis.

4.4.3 Species composition: Table 2 and 3 provide the information on tree and shrub densities in different units and habitat types of Gir. The tree and shrub densities varied significantly in different units and habitats. The tree density (>6 m) was significantly high inside the national park (301± 52.8) as compared to sanctuary west (267± 30.9) and sanctuary east (108.7± 31.8). Similar trends were observed in case of shrub class 2-6 m and 1-2 m. However the density of shrub class 0-1 m was higher in sanctuary west 1038± 322) as compared to national park (766± 259) and sanctuary east (446± 171). Wide variations were found in tree and shrub densities in different habitat types. The tree density (>6 m) and the three shrub categories showed significantly higher densities in *Tectona- Acacia- Zizyphus* woodland (TAZW) , *Tectona-Boswellia-Sterculia* woodland (TBSW) and Mixed Teak Woodland (MTW) as compared to other habitats. The confidence limits were large, indicating the wide variation in density values.

The species composition of various units and habitat types also showed significant differences. *Tectona grandis* dominates the tree layer in sanctuary west (126 trees/ha) and national (165 trees/ha). *Acacia senegal* (11.9 trees/ha), *Acacia catechu* (24.5 trees/ha), *Acacia nilotica* (8.1 trees/ha), *Holarrhena antidysenterica* (13 trees/ha), and *Zizyphus mauritiana* (13.6 trees /ha) were other plant species which dominated the tree layer in sanctuary west whereas *Acacia catechu* (14.5 trees/ha), *Boswellia serrata* (5.8 trees/ha), *Grewia tiliaefolia* (25.4 trees/ha), *Terminalia crenulata* (12.7 trees/ha) and *Wrightia tinctoria* (21 trees/ha) dominated the tree layer in national Park. The tree layer in sanctuary east was dominated by *Terminalia crenulata* (20.5 trees/ha), *Pterocarpus marsupium* (20.5 trees/ha), *Boswellia serrata* (7 trees/ha) and *Acacia catechu* (20.5 trees/ha). The shrub categories (2-6 m and 1-2 m) were more diverse than the tree layer. The densities of different plant species showed wide variations. Thorny species such as *Acacia, Zizyphus* and *Xeromphis spinosa* dominated the sanctuary west and east as compared to the national park. Both shrub categories were less diverse in the national park in terms of abundance of different species and were dominated by *Helicteres isora* (406/ha in 2-6 m and 200/ha in 1-2 m category) and *Wrightia tinctoria* (75/ha in 2-6 m and 50/ha in 1-2 m). These species occurred in uniform patches inside the national park. *Tectona grandis* which dominated the layer did not show the same dominance (Coppice) in three shrub categories. *Anogeissus latifolia* maintains the dominance in these shrub categories inside sanctuary east (97/ha in 2-6 m and 35/ha in 1-2 m). The ratio of teak coppice and teak regeneration is high in shrub category 1-2 m whereas all the teak trees sampled in 2-6 m category were coppiced trees.

The species composition in different habitat types varied significantly. *Tectona grandis* was dominant in TAZW (116/ha) in tree layer. Other co-dominant included *Zizyphus mauritiana* (83/ha), *Acacia catechu* (16.8/ha). *Tectona grandis* was also dominant in TBSW(15/ha) and other co-dominant included *Acacia catechu* (21 trees/ha), *Boswellia serrata* (5 trees/ha), *Emblica officinalis* (5 trees/ha), *Holoptelea integrifolia* (6/ha), *Lannea coromandelica* (5.4/ha), *Soymida febrifuga* (5.4/ha) and *Wrightia tinctoria* (20/ha). Thorny species i.e. *Acacia* and *Zizyphus* showed total dominance in tree layer inside the thorn woodland. *Tectona grandis* (141/ha) contributed largely in the species composition of mixed teak woodland. *Anogeissus latifolia* (40 and 23 trees/ha) along with *Terminalia crenulata* (25.4 and 13 trees/ha) and the thorny species dominated the tree layer in ALTCW and ALBLW. The middle storey was diverse in TAZW, MTW, ALTCW and ALBLW as compared to TBSW and RW where one or two shrub species contributed disproportionately to the shrub layer. The middle layer was poor in case of thorn woodland.

The regeneration and recruitment class (0-1 m) data reveals some interesting facts regarding the regeneration pattern of different plant species in different units. *Acacia senegal, Albizia lebbeck, Albizia procera, Bombax ceiba, Butea monosperma, Boswellia serrata* and *Sterculia urens* showed extremely low regeneration (Table 67).

The plant species which had good regeneration in one or the other unit were *Acacia nilotica, Aegle marmelos, Bauhinia recemosa, Capparis sepiaria, Diospyros melanoxylon, Helicteres isora, Holarrhena antidysenterica, Wrightia tinctoria* and *Tectona grandis.*

Table 4 provides the data on the density of five tree species on the different line transects with fire history and grazing pressure. The teak regeneration decreased as the fire became frequent. However, the density of fire resistant species such as *Acacia catechu* and *Terminalia crenulata* increased. *Tectona- Acacia-Zizyphus* woodland (TAZW) had good regeneration of nearly all tree and shrub species comparatively to other habitats. Teak also showed high regeneration in TAZW.

4.4.4 Species richness and diversity: The maximum species richness and diversity was observed in sanctuary west (Table 5). The species richness and diversity decreased from west to east. Across different height categories, shrub class 0-1 m had the maximum species richness. However, no such pattern was obvious in case of diversity index across various height categories in different units. The species richness and diversity values were not correlated (r_s = 0.534 d.f = 10 P = Not significant).

4.4.5 Mortality pattern: Gir experienced severe droughts during 1986 and 1987. There was high mortality among the populations of several plant species. The overall mortality (percentage dead) for different units of Gir and species specific mortality values are summarised in Table 6. Out of 4151 trees and shrubs (<2 m) of 40 species sampled, 831 were dead. The plant mortality varied significantly between the three units and was high in sanctuary west (22.6%) as compared to national park (18.3%) and sanctuary east (16.7%) (X^2 = 14.4 d.f. = 2 p<.001).

Results also showed that out of 40 species sampled, 39 had suffered mortality. The mortality was not uniform for all plant species. Overall mortality rates were highly variable from 1.7% in *Diospyros melanoxylon* to 82.3% in *Acacia senegal.*

The distribution of individuals of different plant species was found to be skewed. Thirteen plant species were represented by less than 15 individuals sampled and these species were excluded while calculating the mortality for different species.

Overall mortality differed significantly among different plant species and was higher than expected in relation to available proportion of dead trees in *Acacia senegal* (82.3%), *Helicteres isora* (34.1%), *Holarrhena antidysenterica* (76.4%), *Terminalia crenulata* (36.8%) and *Xeromphis spinosa* (52.5%). The remaining species had suffered mortality either in proportion to their availability or significantly lower mortality than expected (Table 7).

The number of individuals of plant species which were common in all three units and had large sample sizes were tested for calculating mortality difference between the units. The species which showed differential mortality in the three units included *Grewia tiliaefolia, Helicteres isora, Holarrhena antidysenterica, Terminalia crenulata* and *Xeromphis spinosa.*

The girth class specific mortality data for different plant species is provided in Fig 9 and 10. The mortality rates thus calculated for different girth classes showed no significant difference in *Acacia senegal, Emblica officinalis, Grewia tiliaefolia, Holarrhena antidysenterica, Terminalia crenulata* and *Xeromphis spinosa.* In these species the expected proportion of dead trees were found within the limits of the Bonferroni confidence interval constructed for each girth class of these species ($p<.05$). In *Tectona grandis*, girth class 0-20 cm had significantly higher mortality whereas girth class 41-60 cm. Showed significantly lower mortality than expected in relation to the available proportion. In case of *Zizyphus xylopyrus*, girth class 0-20 cm data showed significantly lower mortality while girth class 61-80 cm had suffered mortality higher than expected.

4.4.6 Vegetation succession: Figure 11 provides the proposed pathways of succession of vegetation communities in Gir and all the causative factors responsible for the change in vegetation. Several abiotic and biotic factors are responsible in shaping and modifying the vegetation in Gir. The abiotic factors include the topography, soil type, soil moisture, rainfall and drought while biotic factors include the nature and intensity of fire, grazing by domestic livestock, lopping,selective cutting,grass cutting and collection of fruits. The rainfall gradient from sanctuary west to sanctuary east results in disappearance of *Tectona grandis* in extreme east and is replaced by *Anogeissus latifolia*. Even though, the causative and modifying factors are same in both units, the resultant vegetation differs entirely in species composition and distribution.

In sanctuary west, thorn savannah and thorn woodland are clearly the early seral stages of vegetation and are maintained either due to the excessive biotic interference (grazing and browsing) or site factor i.e. Black cotton soil and water in case of thorn woodland and riverine forest. The excessive biotic interference prevents establishment of non thorny species. Development of thorn woodland consisting of mixture of *Acacia* and *Zizyphus* species around the water reservoirs and on abandoned agricultural sites, provides support to this observation. The thorny species colonize the barren land and grassland due to their ability to withstand grazing pressure, large seed production and their dispersal by the herbivores. Generally the understorey remains poor or absent and the ground cover is mainly consisted of the *Cassia tora, Achyranthes aspera* which are indicators of heavy biotic pressures and degraded sites. Further, establishment of thorn savannah by other species is largely governed by the topography and the soil type. The dominant vegetation communities of Gir viz. TAZW, TBSW and MTW have teak as the most dominant plant species in tree layer and only the co-dominant differ in all three habitat types. *Tectona grandis* associates with *Acacia* and *Zizyphus* species on flat areas having deep soil with high clay content while on hills, *Boswellia serrata, Acacia catechu, Lannea coromandelica* are found as co-dominant on extremely rocky and poorly drained laterite soils. In dissected areas and plateaus, the teak associates with *Terminalia crenulata, Emblica officinalis* and *Garuga pinnata.* In case these communities are subjected to repeated severe fire, the regeneration is severely hampered and these communities are reverted back to dry savannah conditions. Repeated fire promote the establishment of fire resistant plant species such as *Terminalia crenulata, Acacia catechu* and *Balanites aegyptiaca.* By all account, these communities qualify to be the climax vegetation types in Gir.

In eastern Gir, *Anogeissus latifolia* dominates the tree layer in all major vegetation types and is distributed on all the topography types. Thorn bushland and thorn savannah are the early successional stages of vegetation development. The topography influencing the plant species distribution, account for the differences in the species composition of *Anogeissus-Terminalia-Butea* woodland distributed on undulating terrain, *Anogeissus-Boswellia-Lannea* woodland distributed on steep hills and the *Anogeissus-Acacia-Zizyphus* woodland found on flatter areas.

4.5 DISCUSSION

The vegetation classification of Gir, done by the polythetic divisive method "Two Way Indicator Species Analysis" by computer programme" TWINSPAN" has been found satisfactory. The conclusions correspond well to the classification done subjectively. The subjective classification by ground surveys, though simple, does not seem appropriate for a homogenous environment. The method is considered to be the most suitable as it takes into consideration maximum information from the species being classified at each dichotomy. Another advantage of this programme is the scope for arrangement of samples and species in ordered two way table (Hill, 1979a). The initial trial of this programme on entire set of vegetation of sanctuary west and sanctuary east together produced somewhat misleading results as *Tectona grandis* and *Anogeissus latifolia* were classified together. These species do not occur together any where in Gir. This necessitated the analysis of sanctuary west and sanctuary east data separately.

Deterended Correspondence Analysis (DECORANA) is again an improved method of ordinating the vegetation data as compared to the reciprocal averaging which suffers with Arch or Horse shoe effect (Hill, 1979b). DECORANA removes the Arch effect by adjusting the values on the second axis in successive segments by centring them to zero mean.

Significant differences were found in cover conditions of vegetation in different management units of Gir. The density and cover has increased in the national park due to the protection given to the vegetation over the last 21 years. As a result, the diversity of palatable plant species has gradually decreased which is by and large detrimental to the large herbivore populations (Khan *et al.*, 1990). Extensive pure patches of *Helicteres isora* dominate the shrub storey inside the national park. This pattern is more obvious in case of shrub class 1-2 m in national park. Apart from *Helicteres isora* densities of other plant species are negligible. In case of shrub class 0-1 m the density is significantly higher in sanctuary west as compared to the national park. This is surprising as one would expect higher regeneration inside the national park due to protection against grazing. Does this mean moderate grazing inside sanctuary west by livestock favour better regeneration? This question requires in depth studies in Gir.

A closer look at the regeneration data of sanctuary east (Table 67) shows that non thorny species such as *Anogeissus latifolia* and *Diospyros melanoxylon* are dominating at the cost of thorny species such as *Acacia catechu*, *Acacia nilotica*, *Acacia senegal* and *Acacia leucophloea*. This phenomenon is contrary to logical expectations since thorny species are adapted to arid and semi arid conditions and they should have dominated in sanctuary east. True less rainfall in sanctuary east is promoting savannah conditions, the same can not be said for the regeneration of different species. Overall the plant species showed a mixed regeneration pattern in different management units i.e. certain species showing extremely good regeneration while others not. *Tectona grandis* shows good regeneration in sanctuary west and poor in national park. However as the shrub class 1-2 m data suggest, its establishment is extremely poor. Further studies are called for to find out the specific effects of grazing, fire and topography on vegetation. It would be rather premature to conclude that regeneration deteriorates in both extremes i.e. over protection as in national park and severe over grazing by domestic livestock as in sanctuary east.

Wide variations were observed in tree and shrub densities in different habitat types of Gir. However no clear pattern could be detected in density values in all four height categories across different habitats apart from the exceptionally high densities in mixed woodland. In absence of any detectable pattern in tree and shrub densities, the variation can not be attributed to any single factor however there is ample evidence that soil characteristics (soil type, depth, moisture etc.) play a crucial role in supporting high plant densities e.g. the *Tectona-Acacia-Zizyphus* woodland is distributed on flat areas in Gir having deep soil with high clay content. The overall composition of different habitat types suggest that vegetation may be gradually changing. The ratio of coppiced teak to regenerating teak is high and teak is loosing the dominance in understorey.

Exclusion of grazing from the national park has brought about considerable changes in the ground cover which is now dominated by perennial grasses such as *Sehima nervosum* and *Heteropogon contortus* compared to sanctuary west and sanctuary east where annual weeds such as *Cassia tora*, *Achyranthes aspera* and grasses such as like *Themeda quadrivalvis* dominate the ground cover. The ground cover dominated by perennials is considered better for ungulates as they are more nutritious (Berwick, 1974) and have fresh growth after early fires (Rodgers, 1986). Considerable efforts are made every year to prevent fires in Gir without realising that early fires are beneficial for ungulates who are mixed feeders consuming both grass and browse in different seasons. However, the role of fire in vegetation dynamics irrespective of the interest of ungulate is unclear and preliminary observations suggest that the repeated fires in Gir affect the tree communities in following ways:

a) The repeated fires cause retrogression (reversal of successional process) and reduction in tree cover leads to dry savannah conditions (Kansvidi area inside national park is the best example where mixed teak woodland and *Tectona-Boswellia-Sterculia* woodland got converted into dry savannah by fire).

b) Burning promotes thorny species such as *Acacia catechu*, *Balanites aegyptiaca* and fire resistant species such as *Diospyros melanoxylon* and *Terminalia crenulata*. Johnsingh (1986) also reported similar increase in the proportion of thorny species in Bandipur with the increase in fire periodicity. *Tectona* *grandis* in spite of being fire resistant, shows a decrease in regeneration. The herbivores also show low densities in savannah despite the fact that water is available throughout the year.

Widespread mortality of different plant species was observed after the monsoon failure in 1987 which created drought conditions. Mortality differed significantly in between the different units and was highest in sanctuary west and national park than in the east. It seems that unusually higher rainfall in the sanctuary east saved the flora in that part while the drought conditions in other parts caused higher mortality.

Mortality in plant populations of this magnitude may have several implications for Gir. Among other things, reduction in cover on short term basis due to removal of dead trees and changes in species composition in the long term due to differential mortality pattern are worth mentioning. The plant communities have a high percentage of species which exist in extremely low densities and mortality in these species may mean further decline in their numbers in future. Even though there contribution is negligible to community structure, they add to the overall diversity of these plant communities.

Table 1. Broad habitat types, distribution and their characteristic tree species in Gir Wildlife Sanctuary.

Habitat types	Distribution	Composition (upper storey characteristic trees)
Riverine woodland	River valleys, whole Gir	S. rubicunda, P. pinnata, Manilkara, F. bengalensis
Thorn woodland	Flat Plain, whole Gir	A. nilotica, A. catechu, Zizyphus mauritiana, A. senegal
Teak - Acacia, Zizyphus woodland	Flat Plain, west Gir	T. grandis, A. senegal, Zizyphus mauritiana, A. nilotica
Mixed Teak woodland	Hills, central Gir	T. grandis, T. crenulata, A. catechu, Lannea, Boswellia
Mixed valley community	Valleys, whole Gir	T. grandis, Pterocarpus, Schrebera swietenioides
Teak - Bosewellia, Sterculia woodland	Higher hills, west Gir	Tectona, Bosewellia, Sterculia, Lannea, A. catechu
Anogiessus - Boswellia Lannea woodland	Higher hills, east Gir	A. latifolia, Boswelia, Sterculia, Lannea, A. catechu
Anogiessus - Terminalia woodland	Lower hills, east Gir	A. latifolia, A. catechu, T. crenulata, Butea monosperma
Pure teak woodland	Hills, west Gir	Tectona grandis
Thorn savannah	Hills, whole Gir	Acacia and Zizyphus species, D. cineria
Thorn bushland	Flat, east Gir	Zizyphus species and D. cineria

Table 2. Tree and shrub densities (various height categories) in different stratum of Gir.

Stratum	n	Tree den.	S.E.	C.L.	Shrub1	S.E.	C.L.	Shrub2	S.E.	C.L.	Shrub3	S.E.	C.L.
S(W)	90	267.7	15.7	30.9	445.5	34.5	67.7	321.6	47.5	93.1	1038	164.4	322.2
NP	90	301.09	26.9	52.8	799.7	76.6	150.3	399.5	30.3	59.5	766.6	132.5	259.7
S(E)	32	108.7	15.8	31.08	318.4	64.2	125.8	185	27.6	54.1	446.6	87.3	171.1

Data at 95% confidence interval

S.E. - Standard Error
C.L. - Confidence Limit

Trees (>6m height)
Shrub1 (2-6m height)
Shrub2 (1-2m height)
Shrub3 (0-1m height)

S(W) - Sanctuary West
NP - National Park
S(E) - Sanctuary East

Table 3. Tree and shrub densities in different habitat types of Gir.

Habitat Type	n	Tree den.	S.E.	C.L.	Shrub1	S.E.	C.L.	Shrub2	S.E.	C.L.	Shrub3	S.E.	C.L.
TAZW	26	249.3	29.9	50.5	360.6	54.8	107.4	356.9	144.9	284.1	1182.70	289.8	568.0
TBSW	132	281.2	15.2	29.8	661.0	54.3	106.5	371.6	23.3	45.7	629.5	52.6	103.2
THW	7	111.1	37.5	73.5	96.2	39.2	77.0	31.8	26.9	52.7	131.8	62.3	122.1
RW	3	106.8	21.8	42.7	273.6	102.8	201.5	391.1	263.0	515.5	1050.5	565.9	1109.2
MTW	13	386.3	54.0	105.8	1094.9	115.5	226.5	457.1	88.5	173.4	1826.8	850.4	1666.9
ALTCW	15	110.8	18.6	36.6	258.7	63.4	124.3	161.2	39.2	76.9	522.0	159.1	311.9
ALBW	15	92.0	26.1	51.1	348.2	118.1	231.5	207.9	44.5	87.3	316.2	76.3	149.5
MVCW	1	265.5	--	--	814.0	--	--	191.0	--	--	1273.0	--	--

Data at 95% confidence interval

S.E. - Standard Error
C.L. - Confidence Limit

Trees (>6m height)
Shrub1 (2-6m height)

Shrub2 (1-2m height)
Shrub3 (0-1m height)

Table 4 Shrub densities (0-1 m) different plant species on different transects with fire history and grazing pressure.

Plant species	Sanctuary West			National Park			Sanctuary East	
	Tran No.			Tran No.			Tran No.	
	1	2	3	4	5	6	7	8
Acacia catechu	78.4	19.6	11.6	5.3	7.4	107.1	17.8	17.8
Balanites aegyptica	29.7	14.8	5.3	0	0	81.7	210.0	18.6
Tectona grandis (Coppic)	9.5	8.4	2.2	5.3	2.1	3.1	10.00	0
Tectona grandis (Regeneration)	47.7	9.5	12.7	7.4	6.3	5.3	0	0
Terminalia crenulata	1.06	1.06	3.1	2.1	1.06	11.6	13.8	15.8
Fire History	1	1	1	2	2	3	1	2
Grazing Pressure	2	2	2	1	1	0	3	3

Fire history, (Past 10 years) 0 = None
1 = Occasional
2 = Frequent
3 = Very frequent

Grazing Pressure 0 = None
1 = Low
2 = Medium
3 = Sever

Table 5 Species richness (S) and Diversity index (DI) for different strata and height categories in Gir.

Stratum	0 - 1 m S	0 - 1 m DI	1 - 2 m S	1 - 2 m DI	2 - 6 m S	2 - 6 m DI	>6 m S	>6 m DI
SW	49	1.20	36	1.06	43	1.25	29	1.36
NP	44	1.24	32	1.82	35	0.99	25	0.76
SE	25	1.05	21	1.05	32	1.70	11	0.66

Table 6 Mortality in different plant species in different districts of Gir.
(n = number of individuals sampled m = number of individuals dead)

Plant species	Sanctuary West			National Park			Sanctuary East			over all mortality %
	n	m	%	n	m	%	n	m	%	
<u>Acacia catechu</u>	139	9	6.4	139	9	6.4	0	0	0	6.4
<u>Acacia chundra</u>	25	5	20.0	26	3	11.5	5	0	0	14.2
<u>Acacia leucophloea</u>	10	0	0	18	1	5.5	15	3	20.0	9.3
<u>Acacia nilotica</u>	86	12	13.9	10	0	0	19	2	10.5	12.1
<u>Acacia senegal</u>	45	41	91.1	0	0	0	6	1	16.6	82.3
<u>Aegle marmelos</u>	0	0	0	0	0	0	133	23	17.2	17.2
<u>Bauhinia racemosa</u>	12	2	16.6	13	0	0	11	0	0	5.5
<u>Boswellia serrata</u>	9	0	0	44	1	2.2	18	1	5.5	2.8
<u>Butea monosperma</u>	39	2	5.1	8	0	0	0	0	0	4.2
<u>Cassia fistula</u>	7	1	14.2	19	4	21.1	0	0	0	19.2
<u>Dalbergia latifolia</u>	3	1	33.3	21	2	9.5	0	0	0	12.5
<u>Dichrostachys cineria</u>	19	7	36.8	2	0	0	11	1	9.1	25
<u>Diospyros melanoxylon</u>	22	1	4.5	18	0	0	17	0	0	1.7
<u>Emblica officinalis</u>	28	9	32.1	40	16	40.0	14	5	35.7	36.5

Grewia tiliaefolia	22	15	68.1	28	1	3.5	3	1	33.3	32.0
Helicteres isora	96	53	55.2	334	95	28.4	4	0	0	34.1
Holarrhena anti-dysenterica	93	76	81.7	114	83	72.8	1	1	100	76.9
Kydia calycina	1	0	0	17	14	82.3	0	0	0	77.7
Lannea coromandelica	13	1	7.6	26	0	0	6	1	16.6	4.4
Millusa tomentosa	5	1	20	19	2	10.5	0	0	0	12.5
Sterculia urens	5	1	20	9	0	0	2	0	0	6.2
Tectona grandis	538	49	9.1	478	29	6.0	0	0	0	7.6
Terminalia crenulata	40	21	52.5	74	23	31	103	36	34.9	36.8
Wrightia tinctoria	150	8	5.3	139	2	1.4	3	0	0	3.4
Xeromphis spinosa	89	56	62.9	27	6	22.2	2	0	0	52.5
Zizyphus mauritiana	130	6	4.6	33	3	9.09	27	1	3.7	5.2
Zizyphus xylopyrus	43	18	41.8	1	1	100	1	0	0	42.2
*TOTAL	1809	410	22.6	1828	335	18.3	514	86	16.7	20.2

* Total includes 13 species which had less than 15 individuals sampled and are not presented in table.

Table 7 Proportion available (P_{io}), proportion dead (P_{ie}) and 95% Bonferroni Confidence limits for different plant species in Gir.

(0 Mortality proportional to availability, - Significantly lower mortality, + Significantly higher mortality)

Plant species	P_{io}	P_{ie}	Confidence limits for P_{ie}			Mortality rating
Acacia	.075	.0235	0.006532	$\leq P_1 \leq$	0.040467	-
Acacia chundra	.015	.0104	0.000963	$\leq P_2 \leq$	0.021763	0
Acacia leucophloea	.011	.0052	0.002855	$\leq P_3 \leq$	0.013255	0
Acacia nilotica	.030	.0182	0.003227	$\leq P_4 \leq$	0.033172	0
Acacia senegal	.013	.0548	0.029308	$\leq P_5 \leq$	0.080291	+
Aegle marmelos	.035	.0300	0.010892	$\leq P_6 \leq$	0.319107	0
Bauhinia racemosa	.0096	.0026	0.003103	$\leq P_7 \leq$	0.00830	-
Boswellia serrata	.019	.0026	0.003103	$\leq P_8 \leq$	0.008303	-
Butea monosperma	.012	.0026	0.003103	$\leq P_9 \leq$	0.008303	-
Cassia fistula	.0069	.0065	0.002500	$\leq P_{10} \leq$	0.015500	0
Dalbergia latifolia	.0064	.0039	0.003081	$\leq P_{11} \leq$	0.010881	0
Dichrostachys cineria	.0085	.0104	0.000963	$\leq P_{12} \leq$	0.021763	0

Diospyros melanoxylon	.015	.0013	0.002735	$\leq P_{13} \leq$	0.005335	-
Emblica officinalis	.022	.0391	0.017389	$\leq P_{14} \leq$	0.060810	0
Grewia tiliaefolia	.014	.0221	0.005633	$\leq P_{15} \leq$	0.038566	0
Helicteres. isora	.116	.1932	0.148978	$\leq P_{16} \leq$	0.237421	+
Holarrhena anti-dysenterica	.055	.2088	0.163274	$\leq P_{17} \leq$	0.254325	+
Kydia calycina	.0048	.0182	0.003227	$\leq P_{18} \leq$	0.033172	0
Lannea coromandelica	.012	.0026	0.003103	$\leq P_{19} \leq$	0.008303	-
Millusa tomentosa	.0064	.0039	0.003081	$\leq P_{20} \leq$	0.010881	0
Sterculia urens	.0042	.0013	0.002735	$\leq P_{21} \leq$	0.005358	0
Tectona grandis	.27	.1018	0.067930	$\leq P_{22} \leq$	0.135669	-
Terminalia crenulata	.058	.1044	0.070150	$\leq P_{23} \leq$	0.138649	+
Wrightia tinctoria	.078	.0130	0.000312	$\leq P_{24} \leq$	0.025687	-
Xeromphis spinosa	.031	.0809	0.050357	$\leq P_{25} \leq$	0.111442	+
Zizyphus mauritiana	.050	.0130	0.000312	$\leq P_{26} \leq$	0.025687	-
Zizyphus xylopyrus	.012	.0248	0.007381	$\leq P_{27} \leq$	0.042218	0

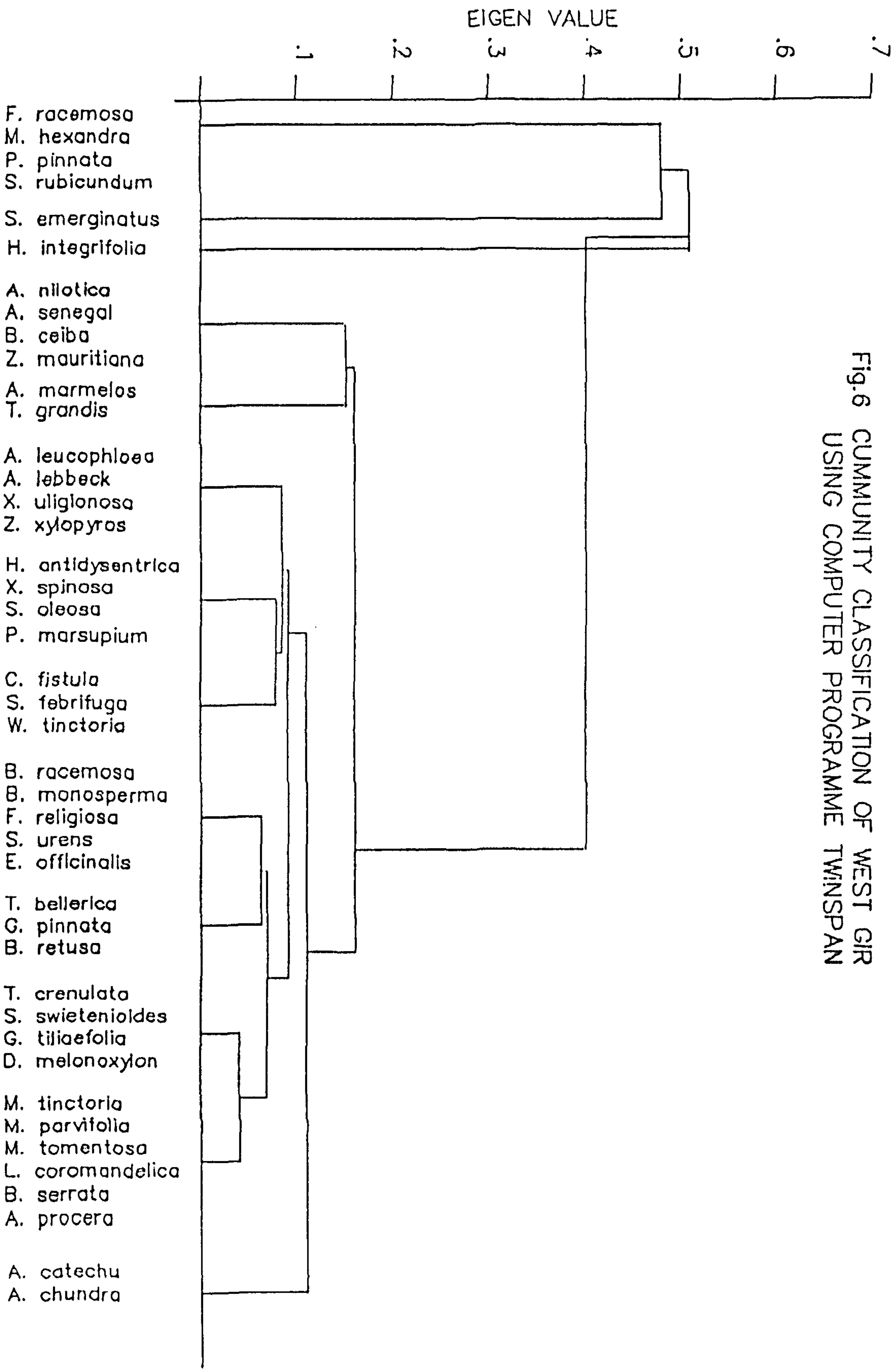
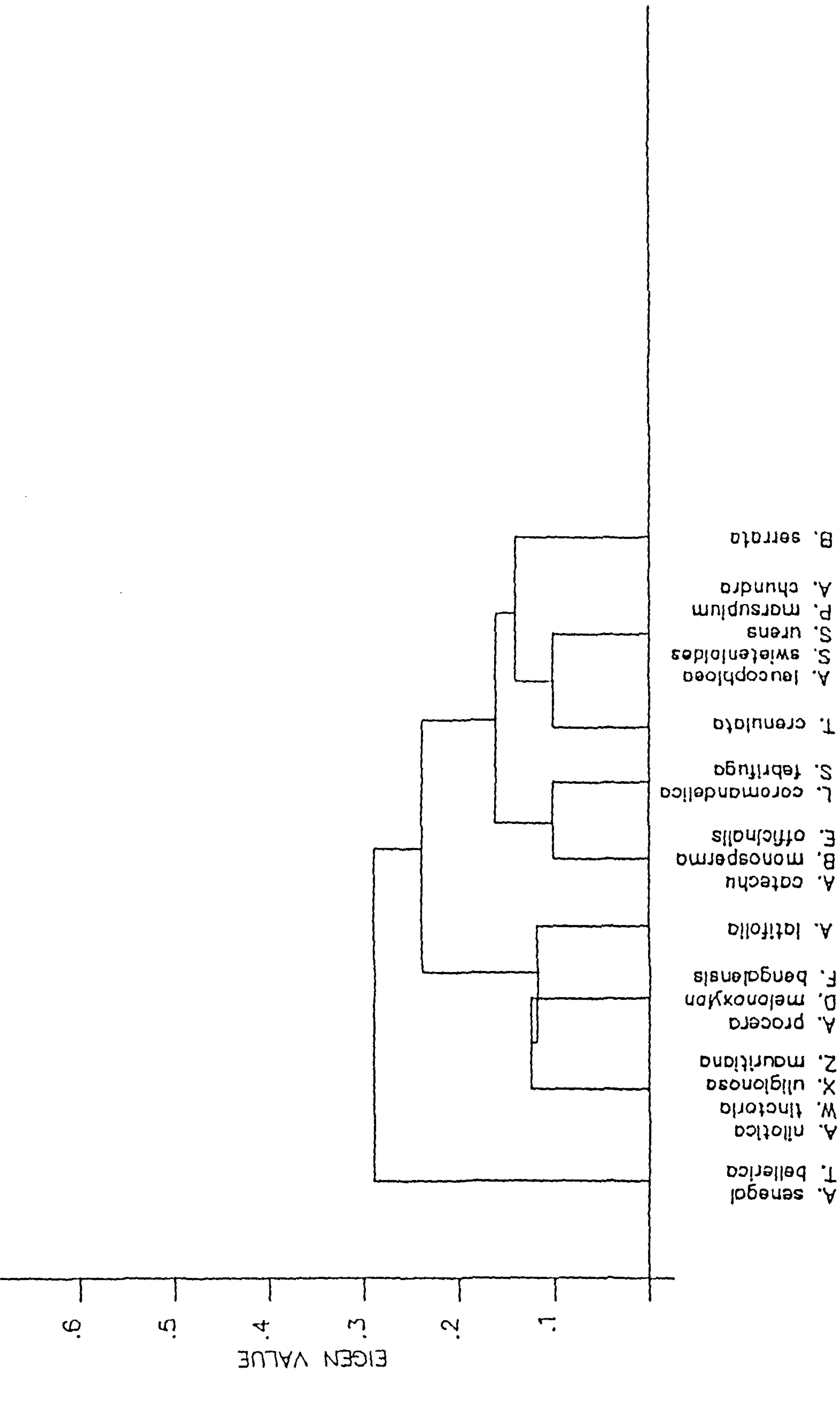


Fig.6 CUMMUNITY CLASSIFICATION OF WEST GIR USING COMPUTER PROGRAMME TWINSPAN

Fig.7 CUMMUNITY CLASSIFICATION OF EAST GIR USING COMPUTER PROGRAMME TWINSPAN



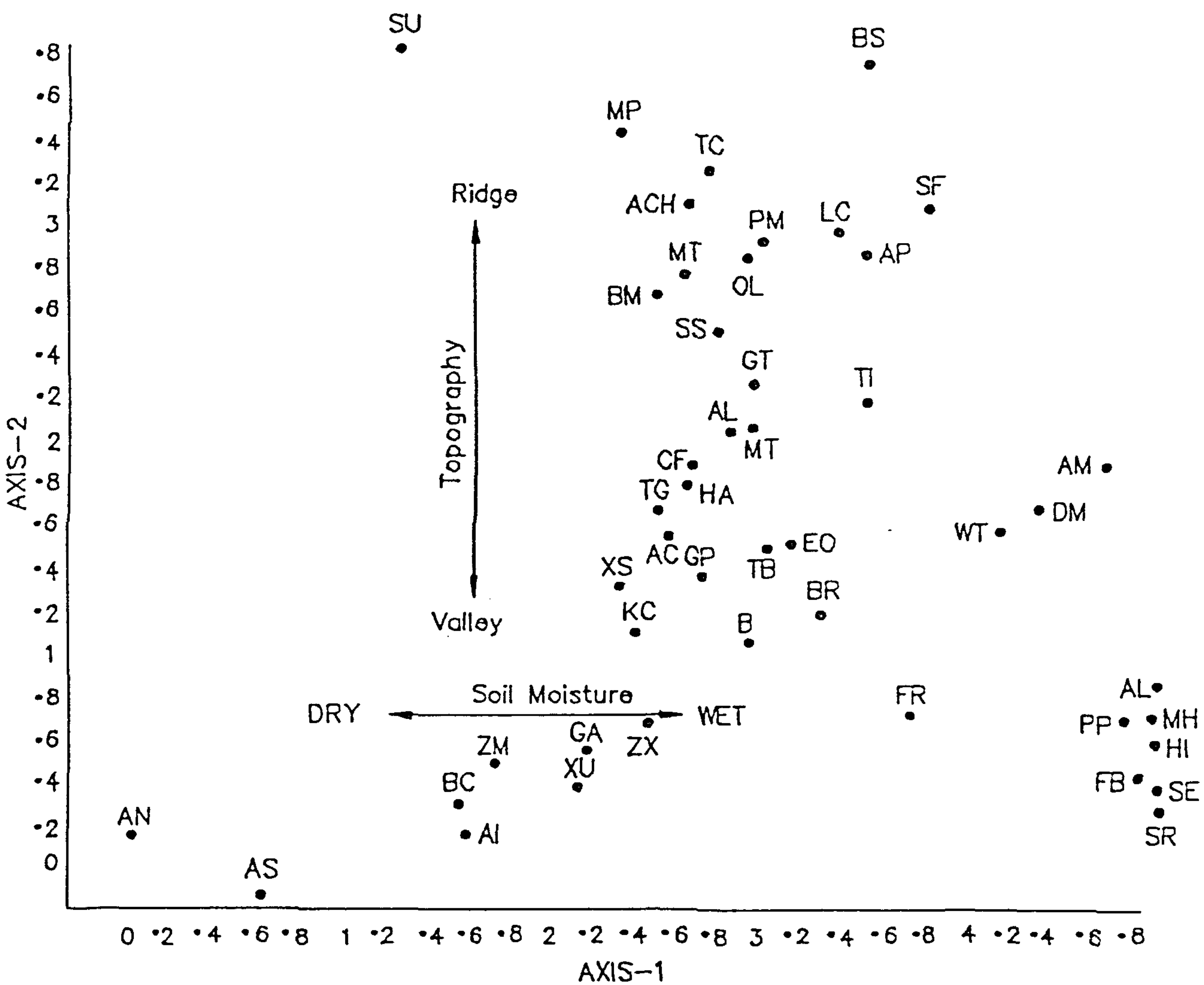


Fig.8 Distribution of different plant species on axis 1 and 2

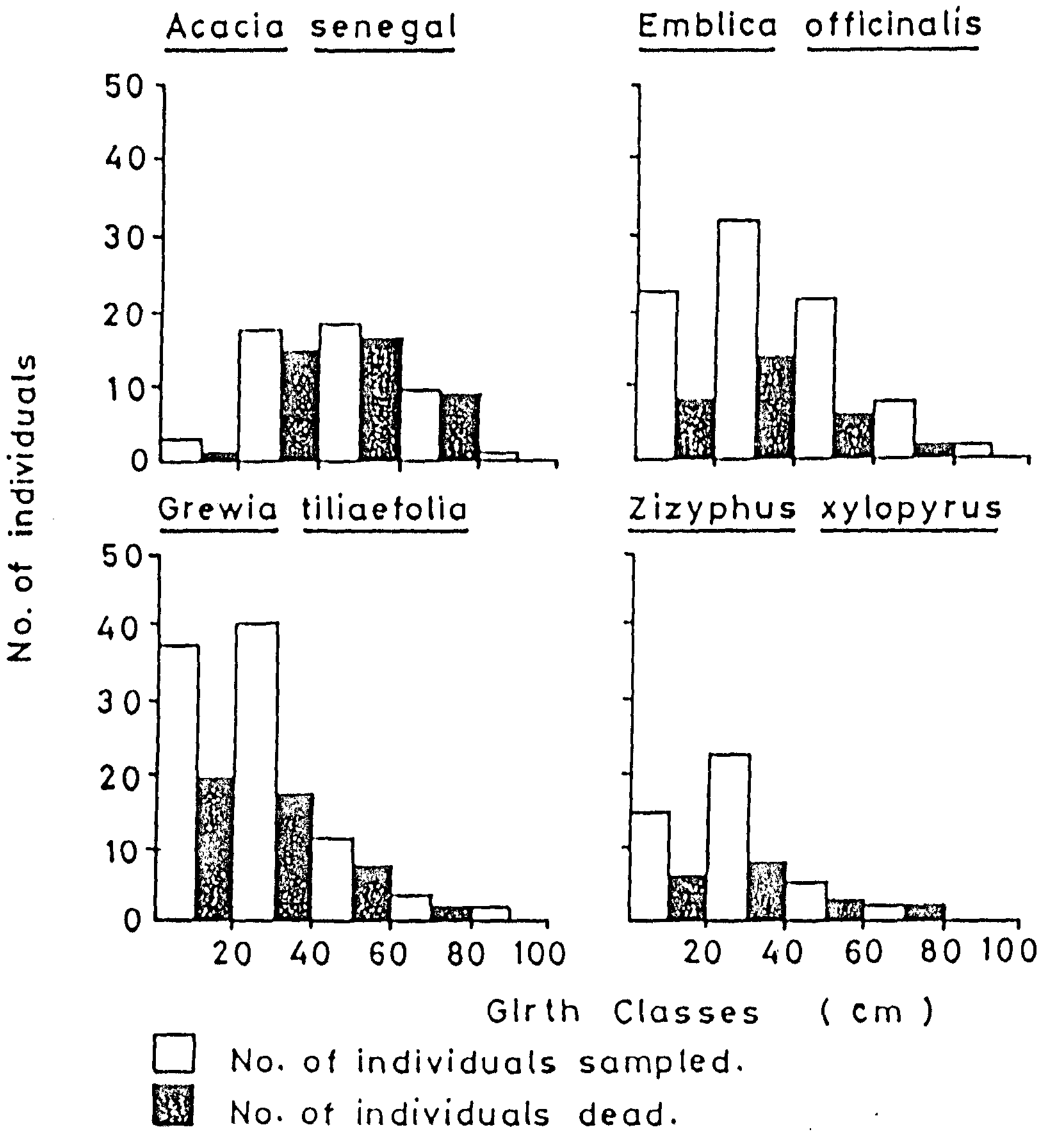


Fig. 9. Number of individuals sampled and found dead of different plant species in Gir Lion Sanctuary.

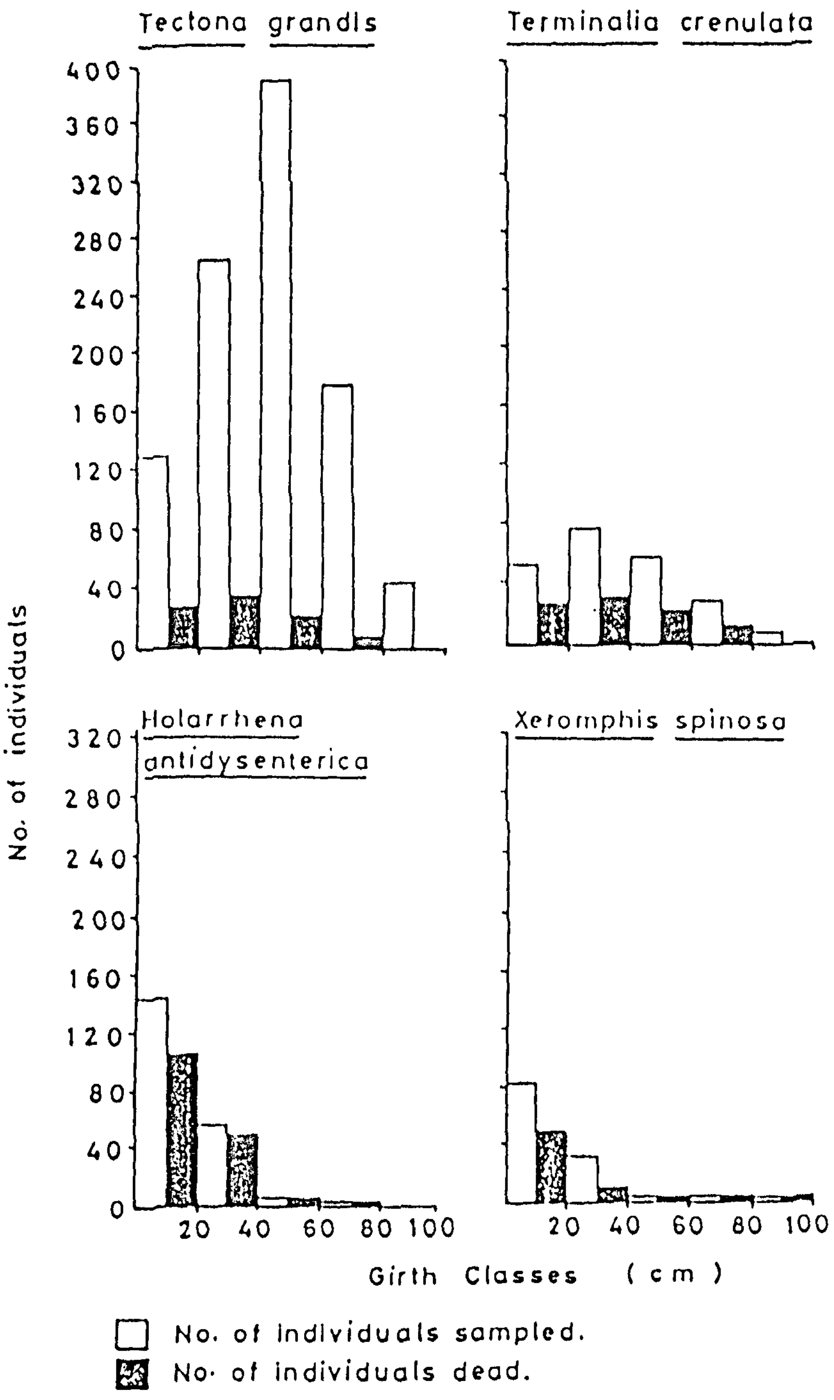


Fig. 10 Numbers of individuals sampled and found dead of different plant species in Gir Lion Sanctuary.

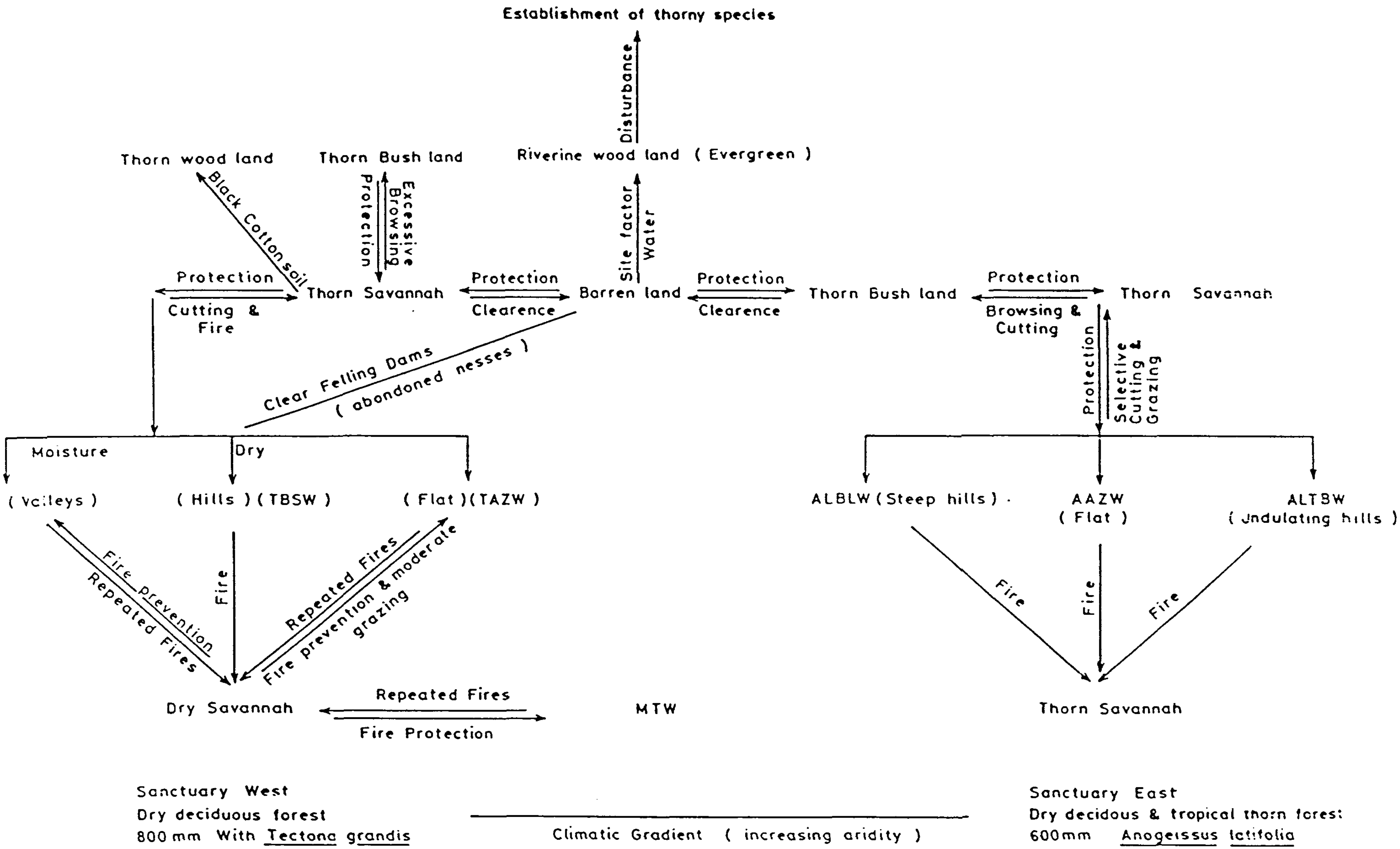


Fig. 11 Proposed Successional relationship among various vegetation communities of Gir Lion Sanctuary

CHAPTER - 5

HABITAT UTILIZATION

5.1 INTRODUCTION: One of the important objectives in management strategy of a wildlife protected area is the successful conservation of ungulate community as it forms part of a larger predator-prey system and therefore often survival of many endangered carnivore species (e.g. tiger, lion etc.) is dependent on it. Moreover their performance in terms of changes in number and distribution can also be used to evaluate the various management inputs in wildlife areas (Cairns and Telfer, 1980; Khan *et.al.*, 1990). To achieve this objective, a sound understanding of habitat requirements of different ungulate species is essential (Hall-Martin, 1974; Dinerstein, 1979; Pettifer and Stumpf, 1981; Balakrishnan and Easa, 1986). This is more so as vegetation (a key component of habitat) is dynamic entity and changes with time either as a consequence of succession, management practices or biotic interference resulting in habitat degradation, modification and fragmentation. Such changes in vegetation are not always conducive to ungulate species and are known to have long term conservation implications for endangered species and wildlife areas (Gilpin and Soule, 1986).

The habitats are complex entities and are composed of a number of interdependent habitat variables. Their occupance by ungulate species is in a way a collective response to the spatio-temporal variation of such interdependent habitat variables (Norman *et al.*, 1975)and therefore quantification of various habitat variables affecting distribution pattern is crucial for their successful management. Research efforts on ungulate-habitat relationships for ungulates in Indian subcontinent (Schaller, 1967;Eisenberg and Lockhart, 1972; Berwick, 1974; Seidensticker, 1976; Dinerstein, 1979; Mishra, 1982) have so far produced qualitative descriptions of their overall habitat occupance based on proportion of sightings of a species in different habitat types and no effort has been made to quantify the various habitat factors controlling the distribution.

The quantification of various habitat factors affecting the distribution of the overall usage of different habitats by animals is a tricky problem particularly when the areas are large and dispersion of different habitat types produces a mosaic. The choice of correct method for quantification of habitat occupance is also important as results may be misleading.

Two approaches have so far been used for quantification of habitat utilisation. The first approach is based on the direct sightings of the target species and the second approach is based on the indirect evidences (e.g. dung). The quantification based on direct sightings reflects the habitat usage only at the time of observation and possible source of error may be due to infrequent or chance sightings, past disturbance and immediate presence of observer. The indirect evidences indicate habitat use round the clock. Quantity of dung for instance, is directly related to the duration of habitat use which provides valuable information and may lead to important conclusions.

The calculation of the ungulate densities in different units of Gir showed significant differences which necessitated the need to understand the overall habitat use and the factors influencing the distribution of all three ungulate species. Basically two data set i.e. direct sightings on walked transects and dung counts have been used. Dung count data had some advantages over direct sightings as it provided enough data for all three ungulate species amenable to statistical analysis.

5.2 DATA COLLECTION : Eight line transects distributed in three units of Gir totalling 48 km were monitored regularly during all the seasons and data on following parameters were collected (see methodology for details).

a) Species and its number

b) Angular and straight line distances

c) Vegetation types and other habitat factors such as topography, slope, canopy cover etc.

The first dung count was done in 1988 winter when Gir was experiencing the worst ever drought of the century and was degraded to extreme level due to grazing by more than 0.1 million cattle. The dung count was repeated in 1989 winter after an exceptionally high rainfall (nearly 1000 mm) . Dung data consisted of pellet groups densities (No. /ha) for chital, sambar and nilgai at 240 sampling points, 200 m apart, along the randomly laid line transects. Each sampling point was characterised by a series of habitat variables.

5.3 DATA ANALYSIS : The sightings of different ungulate species were converted into densities using distance data for different habitat types on seasonal basis. The King census formula was used to calculate the densities.

The diversity of habitats, three different units, 19 habitat variables and a number of ungulate species necessitated the use of multivariate method such as multiple regression analysis (Hirst,1975) to quantify the effect of the habitat variables on distribution of herbivores. Two basic problems were encountered while using multiple regression analysis. Firstly the skewed distribution of some independent variables and secondly the frequent zero values of the variables. A log conversion of the data improved the distribution of habitat variables. Those variables which did not show any improvement after log conversion were not included in the regression analysis. Zeros were replaced by very small values which allowed their inclusion but did not have any impact on the overall analysis of data. The dung densities (2 years data for each habitat types) were subjected to one way analysis of variance (ANOVA) to find out significant difference in the dung densities in the following habitat types: (mean density in each habitat type).

1. *Tectona-Acacia-Zizyphus* woodland (TAZW) : Distributed on flat areas.

2. *Tectona-Boswellia-Sterculia* woodland (TBSW): Higher slopes and rocky areas of sanctuary west.

3. Thorn woodland (THW): On distributed sites and patches of black cotton soil.

4. Riverine woodlands (RW) : River valleys

5. Mixed Teak woodland (MTW): Valleys and plateau.

6. *Anogeissus-Boswellia-Lannea* woodland (ALBLW): Higher hills of sanctuary east.

7. *Anogeissus-Terminalia* woodland (ALTCW) : Flat, undulating areas of sanctuary east.

8. Mixed valley community (MVC) : Valleys.

5.4 RESULTS:

5.4.1 Ungulate densities : The monitoring of foot transects yielded sufficient data only for chital and not for sambar and nilgai as the population densities of these species are very low in Gir. Calculation of sambar and nilgai densities from very small sample sizes would have given misleading picture of their habitat utilisation.

Figure 12 provides the chital densities in different habitat types during different seasons. The densities of chital population calculated through the data collected during 1988 winter indicates a maximum figure of 108.1/ km^2 in TAZW, 51.2/ km^2 in THW and 44.6/ km^2 in RW.The corresponding minimum figures are 13.1/km^2 in TBSW and 19.2/km^2 in ALTCW.

During summer the densities changed in all habitats. The density was highest in MTW (49/km^2) and lowest in TBSW (77.8/km^2).The density decreased significantly in TAZW and RW compared to winter season. During monsoon, the density increased significantly in MTW and declined in TAZW. While density in TBSW and THW remained more or less same, no chital was recorded from riverine habitat and ALTCW. In winter 1989, the density again increased in TAZW (51.1/km^2) THW (106.4/km^2) and MTW (40.4/km^2) while TBSW showed no significant change.

5.4.2 Habitat Preference Index (HPI):

5.4.2.1 Chital : Figure 13 provides the HPI values for chital during winter 1988. The HPI was high in TAZW (5.2), MVC (4.6) and THW (2.8) as compared to other habitats. The lowest HPI was recorded in TBSW (0.37). During summer 1988, the HPI was high in MVC (16.1), MTW (3.6) and ALTCW (2.4). The lowest value was again recorded in TBSW (0.51). During monsoon, the HPI ranged from 4.2 in MTW to 0.60 in THW. The HPI value dropped significantly in MVC and increased slightly in MTW. The HPI in ALTCW, ALBLW, and RW was zero. During winter 1989, the HPI increased significantly in TAZW (5.2) and THW (1.8) while it dropped in MVC (2.9), MTW (1.3) and TBSW (0.55). Zero HPI value was calculated for ALTCW, ALBLW and RW.

5.4.2.2 Sambar : Figure 14 provides the HPI values for sambar during different seasons. During winter 1988, sambar were recorded only in TAZW and TBSW where the HPI values were 1.1 and 1.4 respectively. During summer 1988 the HPI ranged from .06 in TAZW to 24.8 in MVC while the TBSW and MTW had intermediate values of 1.02 and 3.3. There were no sightings in ALTCW, ALBLW, RW and THW. During monsoon 1988, the HPI value increased slightly in TAZW, MTW and MVC while the value for TBSW dropped slightly. No HPI values were calculated for winter 1989 season due to small sample sizes.

5.4.2.3 Nilgai: The sightings of nilgai were very few. Calculation of HPI values for any season was not found feasible.

5.4.3 Ungulate dung densities: The following are the overall results of multiple regression analysis of dung density data for 1988 and 1989.

I. Different habitat variable accounted for the variation in dung density of herbivore species in three different strata.

II. Generally, only a maximum of 57% variation was accounted for by the measured habitat variables.

III. Even though, the overall pattern of habitat utilisation by different herbivore species remained same for the two years, the habitat variables affecting the distribution changed.

5.4.3.1 Chital: The data provided low predictability of chital distribution. In sanctuary west, slope and shrub density (2-6 m height) accounted for maximum variation (32%) in dung density. In national park litter and shrub cover 4 accounted for 23% variation and both factors were positively correlated with dung density (Table 8).

In sanctuary east, Ness distance, rock and mean dung density livestock accounted for 50% variation in chital dung density. Rock and MDD of livestock were negatively correlated whereas Ness distance was found positively correlated with the chital dung density (Table 8) . Analysis of winter 1989 data showed quite different results (Table 9) . Two more new variables i.e. MDD of livestock and Ness distance were found to be affecting the dung density in sanctuary west.

All the four variables accounted for 40 % of the variation in the data. All these factors were found negatively correlated. Rockiness was the only factor weakly influencing the distribution of chital in national park and was negatively correlated. The shrub cover was positively correlated and accounted for maximum variation in chital density (23%) in sanctuary east during winter 1989.

5.4.3.2 Sambar : During winter 1988, sambar dung density in sanctuary west was positively correlated with shrub cover 4 and was the only variable accounting for 23% variation (Table 10). In national park, shrub cover 4, shrub density (1-2 m), bare soil and slope accounted for 49% of the variation in dung density. Except bare soil, all other factors were positively correlated with the dung density. No variable was identified in sanctuary east affecting sambar distribution.

The analysis of 1989 data showed a similar pattern. As compared to previous year, four new variable i.e. MDD of livestock tree density, rock and grass cover accounted for maximum of 38% variation in the dung density. Except MDD of livestock, all other factors were positively correlated (Table 11). Inside national park, apart from the factors identified in 1988, litter and shrub density (2-6 m) were two more variables which accounted for variation in sambar dung density. All these factors nearly accounted for 57% of the total variation. Except MDD of livestock all other factors were negatively correlated. Ness distance was the only factor identified in sanctuary east to influence sambar distribution. The correlation being negative, Ness distance accounted for only 14% of the total variation.

5.4.3.3 Nilgai: The nilgai dung density data gave a very low predictability for nilgai distribution for 1988 and 1989 (Table 12 and 13). During 1988, tree density was the only variable identified in sanctuary east which influenced the distribution of nilgai. It accounted for only 9% of the variation and was found to be negatively correlated. Inside national park too only one variable i.e. shrub cover 1 was identified to be weakly influencing the nilgai dung density. Shrub cover 1 and shrub density 2 were the two factors which accounted for 32% of the variation. The shrub cover was positively correlated.

The analysis of winter 1989 data produced very low predictability of nilgai distribution. Slope was the only factor which accounted for 13% of the variation in sanctuary east and was found to be positively correlated.

5.4.4 Use of habitat types : The result of one-way analysis of variance showed that use of different habitat types was not uniform and the three ungulate species preferred certain vegetation types over the others. Chital dung density was significantly higher in TAZW,THW and TBSW as compared to RW, MTW, ALTCW, ALBLW, and MVC. Chital preferred these habitat types in decreasing order (Table 14 and 15). Sambar mean dung density was significantly higher in MTW, TBSW and

TAZW as compared to other habitat types. Sambar used these habitats in decreasing order (Table 16 and 17).

Nilgai mean dung density was significantly higher in ALTCW and ALBLW in comparison to all other habitats (Table 18 and 19). The pattern of habitat use remained same between the two years of dung data ($r_s = 0.86$ $p < .05$). However the mean dung densities of different ungulate species were higher in 1988 than 1989. Dung pellets sampled during winter 1988 included pellet groups of previous two years because of severe drought, however, Gir had exceptionally higher rainfall during 1988 and therefore dung pellets of only four months duration were sampled in 1989.

5.5 DISCUSSION

The study of habitat utilisation pattern or more specifically the habitat preference and avoidance of a particular herbivore species or a group of species has been a central theme in almost all studies which aimed at evaluating the impact of past management and land use practices for development of effective management strategies for wildlife areas. These studies utilised a variety of techniques based on either indirect evidences i.e. Dung, tracks etc. (Dalke *et al.*,1965; WetZel,1975; Kearney and Gilbert, 1976; McCaffery,1976; Short *et al.*, 1977; Lyon and Jensen, 1980; While and Eberhardt, 1980; Collins, 1981) or direct evidence i.e. sighting of animals (e.g. Martinka,1968; Constan, 1972; Larson *et al.*, 1978; Mooly *et al.*, 1987; Cederlund and Okarma, 1988). The data collected based on indirect evidence has been analyzed in a variety of ways from simple calculating the abundance of pellet groups in different habitats to the calculation of habitat utilisation Index (HUI) (Suring and Vohrs, 1979). Similarly the animal sightings sampled either by monitoring line and road transect or using radio locations (Schoen and Kirchoff,

1990) has also been analyzed in a variety of way from simple calculation of animal sighting frequency in different vegetation types to use of multivariate statistical techniques (Daniel Edge *et al.*,1987; Edge *et al.*, 1987, Ferrar and Walker, 1974; Norman *et al.*,1975) to understand animal distribution. However both approaches have several limitations which are hard to be met in field and inadequate data to support them.

Neff (1968) reviewed the use of pellet group counts in wildlife studies and cautioned particularly for using this technique for finding out the habitat use. There is little data to support the two assumptions i.e. the rate of faecal deposition is a linear function of time, and that average depositions rates within individual adjacent habitats are similar. Although Putman (1984) advocated the use of this technique due to several advantages, the assumptions have been found to be untrue. The use of sightings of animals though simple, also have several problems such as necessity of equal sampling of all the habitats, chance sighting and influence of past disturbance etc. Considering these limitations, a combination of both these approaches was used in Gir. The line transects were laid and monitored to find out the seasonal occupance of different habitat types and sampling of pellet groups in different habitats was done in one season to look at the factors governing the distribution of herbivores in Gir. The methodology adopted however did not work satisfactorily. The line transects yielded inadequate data for sambar and nilgai which was not amenable to any statistical analysis. Thus the observations were limited in case of line transect to chital (densities and HPI both) and sambar (HPI only) on seasonal basis. The pellet group data though for all three herbivores was limited to only winter 1988 and winter 1989.

The results of density, habitat preference index and pellet group data showed discrepancies in habitat utilisation pattern of chital during winter season. While there was broad agreement for two most preferred habitats (TAZW and THW),between three data sets, the values differed for one habitat (TBSW). The chital density was low in TBSW throughout the year, but a very high dung density of chital was recorded in TBSW. Contrary to this the HPI value was high for mixed valley community. The discrepancy between the density and dung pellet group abundance violates the basic assumption that the defecation of an animal is a function of time spent by animal in each habitat. No study has so far been done on defecation pattern of any south east Asian deer however studies on mule deer and white tailed deer suggest a differential defecation pattern between the habitats. There were significant differences between the time spent by while tailed deer and the pellet group deposition. The maximum defecation occurred between the bedding and feeding sites. It is possible that chital used TBSW for resting during night time and came down to valleys and flat areas for feeding in morning. As monitoring was done during morning hours, a very high density was recorded in TAZW, THW and RW distributed in valleys and flat areas and having the maximum inter-dispersion of habitats. As for high HPI value for MVC habitat, it resulted due to low proportion of habitat coverage and very few sightings which produced a highly skewed value of HPI.

The densities of chital in different vegetation types and the HPI values suggest that the density differed significantly among vegetation types and was high in TAZW, THW and RW during winter season. The density as well as HPI values also showed seasonal variation. TAZW and THW habitat contain high abundance of *Acacia* and *Zizyphus* species. Maximum interspersion also occurs among TAZW, THW and

RW. *Acacia* and *Zizyphus* species attain their peak fruiting during November and December which persists till March. Dietary observations suggest that during winter chital population largely subsists on these fruits due to high nutritional demand of lactating females (peak fawning occurs during November-December). Moreover the grasses mature by winter time and are low in their protein content. A high density of plant species due to interdispersion (Ecotone) and super abundance of fruits make these habitats optimum for chital during winter. This scenario changes during summer as fruiting is over and most of the grass biomass is removed by the livestock. The trees also shed their leaves during early summer. The density drops in all three habitats and only mixed teak woodland showed significant increase in density. Monsoon season showed further increase in chital density in MTW and a drop in TAZW and THW habitat while the densities remained same in TBSW and RW. This is surprising because monsoon improves food and water conditions in their habitats. It is possible that these habitats differ in terms of the quality of forage available to chital. Due to heavy grazing in these habitats the grasses rejuvenate very slowly in Gir and in the beginning, ground cover is dominated by weeds such as *Cassia tora* , *Achyranthes* and *Impatience balsamina*. These weeds continue to dominate till their flowering period after which grasses grow in these habitat and change the species composition of ground cover. During winter, the pattern is reversed and TAZW, THW and RW show significantly high densities.

Despite the obvious differences in the distribution of mean dung densities for three herbivores species within the habitat types, the measured variables give a low predictability of distribution of ungulate species in three units. There are four possible reasons for such a low predictability. The first two reasons are associated with methodology. Is the animal dung robust enough to give a correct picture of the actual distribution of ungulate species? Or are the measured variables not complete? Are there some more habitat factors which are more crucial then the measured ones? Even though no information is available on Indian ungulates regarding defecation pattern and the factors associated with it, it is likely that dung may not be the correct dependent variable to be used in the analysis. It is also likely that the list of independent habitat variables was not complete, but not to the extent that large amount of variation remained unaccounted for. The selection of variables was done keeping in view the crucial requirement of the ungulates (e.g. cover, food, water etc) and secondly all previous studies (Schaller, 1967; Berwick, 1974;Sharatchandra and Gadgil,1975; Johnsingh, 1983) emphasised the importance of either food, cover or topographic factors in affecting the overall distribution.

The other possible explanations are equally convincing and may actually be responsible for such low predictability. Firstly all key habitat variables do not show wide variation across the three units of Gir. The changes are subtle with some level of uniformity in cover and topography. Conditions unlike Chitwan or Dudhwa where differences in woodland and grassland conditions are able to produce pronounced effects on ungulate distribution are lacking in Gir. The only variable, which in a normal monsoon year varies greatly in the level of disturbance across the three units. However, 1987 being a drought year and livestock grazing all over the Gir, the effect of disturbance factor also got minimized. Secondly all three ungulate species are generalist i.e. subsisting on a mixed diet of grass and browse and adapted to a variety of topography and vegetation types. In such a situation, it is highly unlikely that their distribution will be strongly influenced by one or a combination of habitat component as is the case with highly specialised species such as swamp deer which requires short grasslands (Martin, 1977).

In a drought year, the changes in the quality of habitats are obvious and uniform as compared to normal monsoon year. In such a situation, one would expect that food availability and water will have more significant influence on the distribution of three ungulate species than any other habitat variables (e.g. Rockiness or cover etc.). In other words they may be becoming limiting in real sense. However after exceptionally high monsoon in 1988 in Gir, when food and water being available far and wide, the effect of other factors may be more obvious (eg. Ness distance and MDD livestock are more obvious in 1988 data compared to 1987). The variables identified during winter 1987 and 1988 for chital suggest some level of similarity, even though variables changed in the three units. The common pattern which emerged from two years data in case of chital was.

I. Avoidance of slope in one or the other unit i.e. concentration in productive and wetter valleys.

II. Avoidance of pastoral settlements as chital dung density is positively correlated with Ness distance and avoidance of areas which are heavily used by livestock because chital dung density also showed a negative correlation with livestock dung density.

The pastoral settlements are generally located in valleys near perennial water sources and maldharis also take the livestock where conditions of grass cover remain good. Being primarily a grazer, it is likely that chital will avoid heavily grazed ares.

Very little information exists on ecology of sambar despite the fact that it is widely distributed in Indian subcontinent. Schaller (1967) and Berwick (1974) found that sambar prefers dense shrub cover and hilly terrain. Utilisation pattern worked cut using HPI values cannot be reviewed upon due to the fact that they have been calculated from a very low sample size and presents a distorted picture of its habitat occupance. The pattern which emerged for sambar for two year dung density data was:

I. Preference for hilly and rocky terrain.

II. Preference for high tree and shrub cover as dung density was found to be positively correlated with different cover categories.

III. Avoidance of areas used by livestock and pastoral settlements.

Sambar are generally solitary or live in small groups. It uses variety of strategies to avoid predators which includes freezing and remaining motionless in thick cover (Johnsingh, 1983). Preference for hilly terrain and dense shrub cover confirms this pattern as observed else where also.

Nilgai generally prefers open and undulating areas in Gir (Berwick, 1974) and analysis of dung density is in close agreement as it shows a negative correlation with tree and shrub density. Both years data suggest nilgai dung density was significantly higher in ALTCW and ALBLW. These two habitats are distributed in sanctuary east and it is where highest densities of nilgai were recorded. Both these habitat types are characterised by low tree and shrub densities, undulating terrain, dominance of thorny species and grasses which are all typical habitat requirements of nilgai (Schaller, 1967) considering its large body size and adaptability to degraded environment. Other habitats in sanctuary west and national park have shown significant increase in cover density which is largely rendering these areas unsuitable to nilgai. In fact a slight decrease has been noticed in nilgai density in these two areas from 1967 (Khan *et al.*, 1990)

Table 8. Result of multiple regression analysis on Chital dung density data, Winter 1988.

Step No.	Variables	Stratum	Correlation	R^2 Value
1	Slope	Gir(West)	-	0.22
2	Shrub3	Gir(West)	+	0.32
1	Litter	N.P.	+	0.18
2	Shrubcover4	N.P.	+	0.23
1	Ness distance	Gir(East)	+	0.17
2	MDD Cattle	Gir(East)	-	0.34
3	Rock	Gir(East)	-	0.50

Table 9. Result of multiple regression analysis on Chital dung density data, Winter 1989.

Step No.	Variables	Stratum	Correlation	R^2 Value
1	MDD Cattle	Gir(West)	-	0.20
2	Slope	Gir(West)	-	0.32
3	Ness Distance	Gir(West)	-	0.37
4	Shrub Cover	Gir(West)	-	0.40
1	Rock	N.P.	-	0.09
1	Shrub Cover	Gir(East)	+	0.23

Table 10. Result of multiple regression analysis on Sambar dung density data, Winter 1988.

Step No.	Variables	Stratum	Correlation	R^2 Value
1	Shrub Cover4	Gir(West)	+	0.23
1	Shrub Cover4	N.P.	+	0.30
2	Shrub2	N.P.	+	0.41
3	Bare Soil	N.P.	-	0.45
4	Slope	N.P.	+	0.49

Table 11. Result of multiple regression analysis on Sambar dung density data, Winter 1989.

Step No.	Variables	Stratum	Correlation	R^2 Value
1	MDD Cattle	Gir(West)	-	0.21
2	Tree Density	Gir(West)	+	0.30
3	Rock	Gir(West)	+	0.35
4	Grass Cover	Gir(West)	+	0.38
1	MDD Cattle	N.P.	-	0.39
2	Tree Density	N.P.	+	0.47
3	Shrub3	N.P.	+	0.51
4	Litter	N.P.	+	0.54
5	Rock	N.P.	+	0.57
1	Ness Distance	Gir(East)	-	0.14

Table 12. Result of multiple regression analysis on Nilgai dung density data, Winter 1988.

Step No.	Variables	Stratum	Correlation	R^2 Value
1	Tree Density	Gir(West)	-	0.09
1	Shrub Cover1	N.P.	+	0.05
1	Shrub Cover1	Gir(East)	+	0.19
2	Shrub2	Gir(East)	-	0.32

Table 13. Result of multiple regression analysis on Nilgai dung density data, Winter 1989.

Step No.	Variables	Stratum	Correlation	R^2 Value
1	Slope	Gir(East)	+	0.13

Table 14. Result of one-way analysis of variance of habitat utilization data of chital for Winter 1988.

Habitat type	Mean dung density	ALBLW	ALTCW	MT	RM	TBSW	THW	TAZW
ALBLW	1.74							
ALTCW	2.13							
MT	5.75							
RH	7.20							
TBSW	11.21	X	X					
THW	7.24	X	X					
TAZW	15.90	X	X				X	

X Denotes pairs of groups significantly different at < 0.05 level.

Table 15. Result of one-way analysis of variance of habitat utilization data of chital for Winter 1989.

Habitat type	Mean dung density	ALBLW	ALTCW	MT	TBSW	RH	THW	TAZW
ALBLW	0.55							
ALTCW	0.93							
MT	2.30							
TBSW	2.31	X						
RH	3.33							
THW	4.50	X	X					
TAZW	6.56	X	X	X	X			

Table 16. Result of one-way analysis of variance of Sambar dung density for Winter 1988.

Habitat type	Mean dung density	ALBLW	ALTCW	THW	TAZW	TBSW	RH	MT
ALBLW	0.0							
ALTCW	0.13							
THW	0.21							
TAZW	1.25	X	X					
TBSW	1.31	X	X	X				
RH	1.40							
MT	1.44	X	X					

X Denotes pairs of group significantly different at the < 0.05 level.

Table 17. Result of one-way analysis of variance of Sambar dung density for Winter 1989.

Habitat type	Mean dung density	ALBLW	ALTCW	THW	TAZW	RH	TBSW	MT
ALTCW	0.8							
ALBLW	0.13							
THW	0.14							
TAZW	0.42							
RH	0.75							
TBSW	1.05	X	X	X	X			
MT	1.42	X	X	X	X			

X Denotes pairs of groups significantly different at the < 0.05 level.

Table 18. Result of one-way analysis of variance of Nilgai dung density for Winter 1988.

Habitat type	Mean dung density	RM	TBSW	MT	TAZW	ALBLW	THW	ALTCW
RH	0.0							
TBSW	0.015							
MT	0.014							
TAZW	0.057							
ALBLW	0.10							
ALTCW	0.16		X					

X Denotes pair of groups significantly different at < 0.05 level.

Table 19. Result of one-way analysis of variance of Nilgai dung density for Winter 1989.

Habitat type	Mean dung density	THW	RH	MT	TBSW	TAZW	ALBLW	ALTCW
THW	0.0							
RH	0.0							
MT	0.0							
TBSW	0.0019							
TAZW	0.0096							
ALBLW	0.0667			X	X	X		
ALTCW	0.1167	X	X	X	X	X		

X Denotes pairs of groups significantly different at the < 0.05 level.

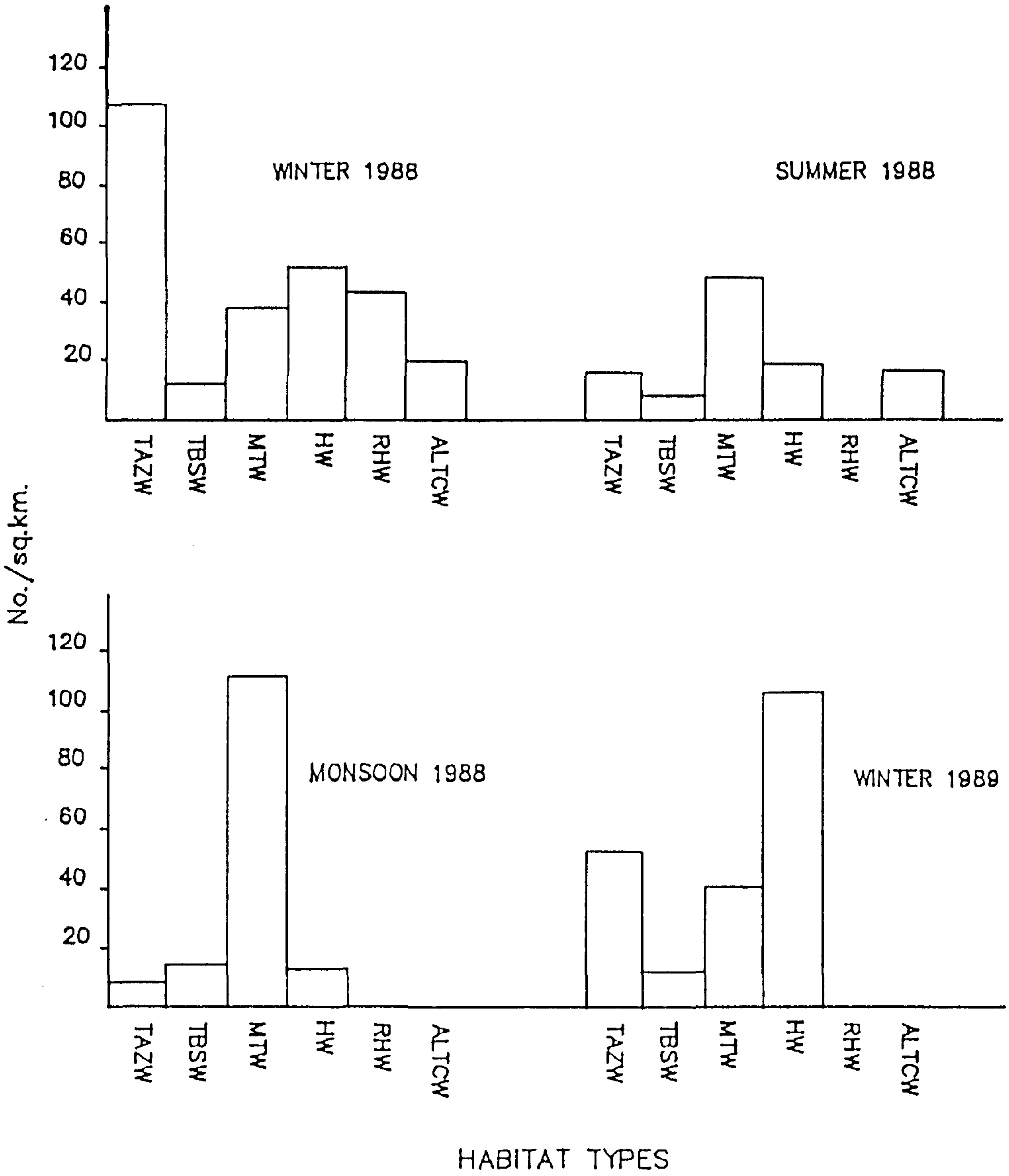


Fig. 12 Chital densities in different habitat types during different seasons in Gir Lion Sanctuary

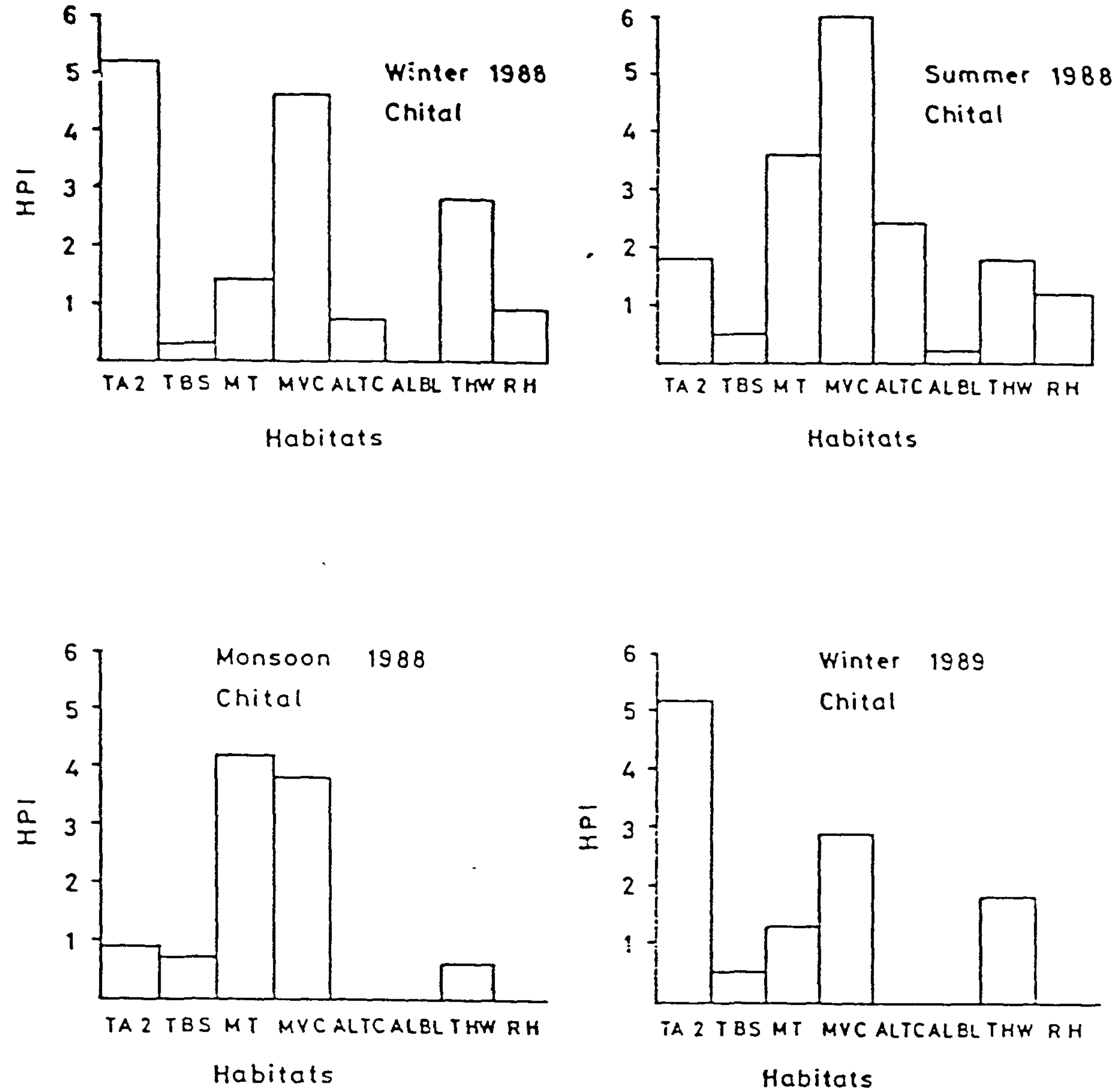


Fig. 13 Habitat preference index of Chital during different seasons in Gir.

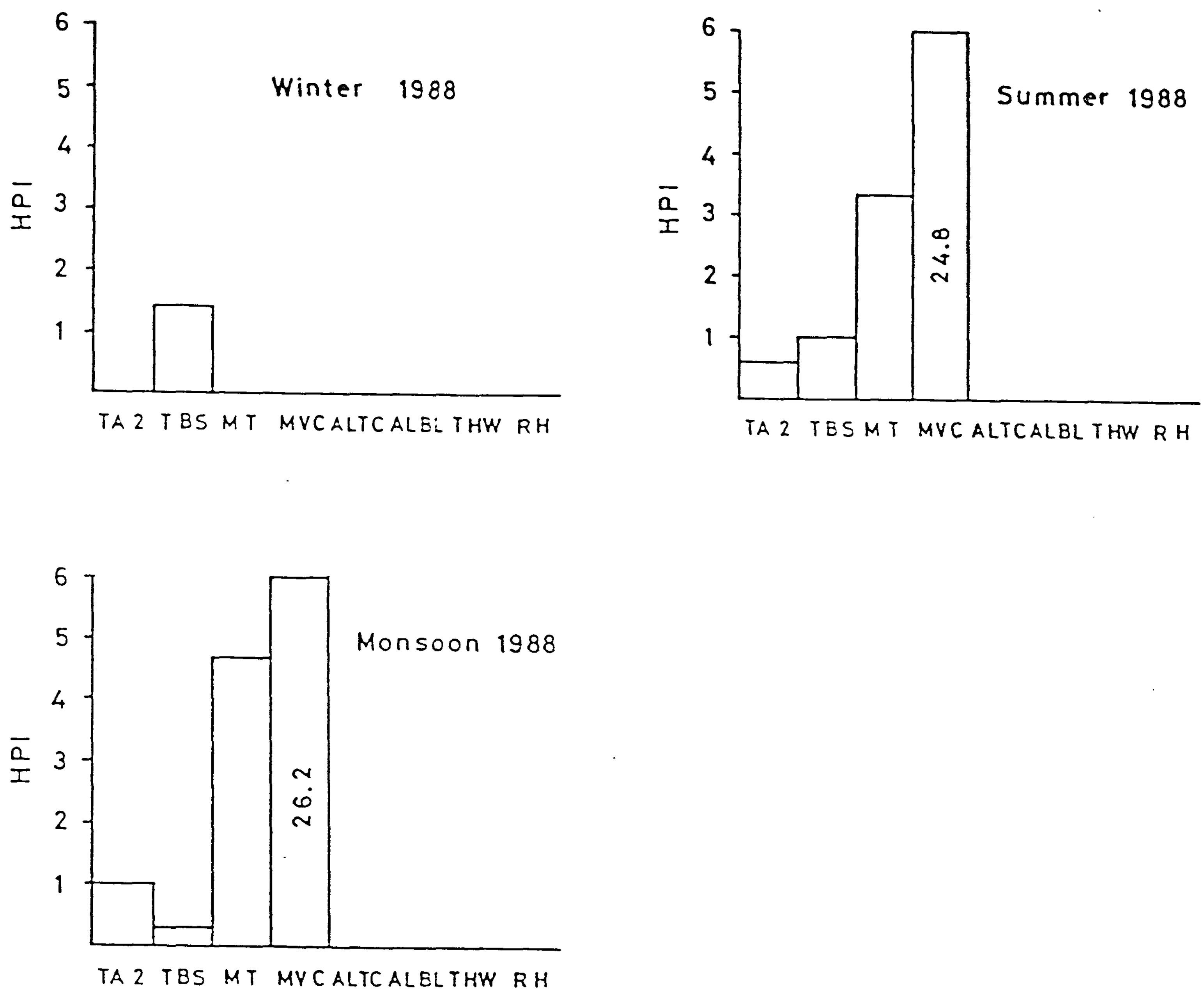


Fig. 14 Habitat preference index of Sambar during different scasons in Gir.

CHAPTER - 6

UNGULATE DENSITIES, DISTRIBUTION & NUMBER

6.1 INTRODUCTION:

The theory and concepts of line transect method for sampling the populations have been investigated quite rigorously in past two decades (e.g. Eberhardt,1968; Gates *et al.*,1968; Overton and Davis,1969; Anderson and Pospahala, 1970; Seber, 1973; Burnham and Anderson, 1976; Burnham, 1978; Pollock, 1978; Anderson *et al.*, 1979; Burnham *et al.*, 1980). This method has been used extensively to estimate populations of a number of species however, similar efforts are lacking in Indian conditions and preliminary informations on population status of several species are deficient. This has resulted mainly due to lack of sound methods applicable in Indian conditions and lack of efforts in this direction. There are a number of animal species which do not have large viable populations in wild and it is very much desirable to monitor the status of such species. The existing literature on census methodology, though very extensive has not been tested and developed in terms of their suitability in diverse Indian conditions. The idea of estimating the ungulate populations in Gir was two pronged. Firstly Gir harbours the only surviving population of Asiatic lion and its sound management would require a thorough estimate of its prey base. Secondly the ungulate populations are directly affected by the overall changes in the structure and composition of various habitat types and the management input.

Continuous monitoring of these populations would either justify the past management input or help their modification. The following chapter describes the result of vehicle censuses and foot transects carried out in Gir.

6.2 DATA COLLECTION : Four vehicle censuses were carried out in Gir during different seasons(Table 73). These censuses were spread over the whole season. Eight permanent transects of six km each were used for line transect census. These transects were monitored regularly during each season.

6.3 DATA ANALYSIS : Vehicle census data were analyzed by King's and Kelker belt method manually. Fourier series estimation was done using the Computer Programme "Transect" developed by Laake *et al.*, 1979) . Data from all road transects of each censuses (Collected in five m classes) were grouped in 10 m classes to remove the heaping from the data . Table 78,79,80,81 and 82 contain data on animal group sighting frequency per distance class interval for different censuses. Mean perpendicular distances (M.P.D.) were calculated from the group sighting frequency data obtained during summer 1987 and winter 1988 censuses. These M.P.D. values were used in the density estimation by King's method. An overall density figure for each ungulate species was calculated by pooling the data from all transects and using overall mean perpendicular distance values for each species. Confidence limits were calculated around the mean density achieved from individual transects. Effective strip width (E.S.W.) for Kelker belt method was estimated by plotting the group frequencies against the distance class interval. The value of E.S.W. varied according to the different strata. The grouped data with a specified width has been used for the Fourier series analysis. The length of the width used was either based on the maximum perpendicular distance or was decided after the data truncation. Data truncation involved rejection of extreme sightings. Generally one to three percent extreme sightings were removed from the grouped data. The densities were calculated according to different strata. Data sets having small sample sizes (< 15) were not used for overall density estimation by Fourier series estimator. The line transect data were analyzed using King's method manually and the Computer programme "Transect". The sighting angles were calculated for different seasons by pooling the data. The value of mean sighting angle decided the choice of method used for calculation of density (Table 85).

6.4 RESULT: The result of ungulate density estimates are discussed for each vehicle census carried out in Gir.

6.4.1 Vehicle count summer 1987 : Marked variations were seen in the densities of angulate species in different strata. The density of chital was found to be maximum in sanctuary west ($63.4 \pm 7.8/km^2$) as compared to national park ($45.4 \pm 7.4/km^2$) and sanctuary east ($20.3 \pm 9.9/km^2$). Diversity of habitats and their interdispersion, an abundant food supply in terms of palatable *Acacia* and *Zizyphus* species, year round availability of water and flat areas are some of the factors which make the sanctuary west the most suitable habitat for chital in Gir.

The extremely hilly terrain and low water availability throughout the year in national park not only resulted in uneven utilisation of resources but also limited capacity of these habitats to support high chital densities. Sambar density was maximum in the national park ($5.9 \pm 1.7/km^2$) which was higher than the overall sambar density in Gir ($3.06 \pm 0.68/km^2$) and sanctuary west (Table 22). Dense shrub and tree cover and the hilly terrain made the national park best habitat for sambar in Gir. The sightings of sambar in sanctuary east were very few and hence could not be considered for analysis (Table 22). Analysis of data leads to estimations of densities of nilgai ($0.51/km^2$), chowsingha ($0.92 /km^2$) and wild boar ($0.65/km^2$).

The densities were extremely low as compared to chital and sambar. Gir once had very high densities of nilgai and wild boar populations (Berwick, 1974) but due to agricultural expansion all around Gir and their severe involvement in crop raiding, the protection devices such as live wires of electricity spread on the boundaries of crop fields took a very heavy toll of these animals. Chowsingha density was very low and appeared to be optimum for Gir considering the fact that the predation on these animals was difficult to account for and figures from other wildlife areas were not available for comparison.

The ungulate density analysis by different methods, (King's Kelker belt and Fourier series) yielded similar results except that the density estimates achieved) by Kelker belt were sightly lower than those obtained by application of King's and Fourier series methods (Table 20). The confidence limits achieved by all three methods were narrow. The individual transect densities showed significant spatial variation throughout Gir. The lower estimates of chital with the Fourier series for sanctuary east was probably due to the data truncation. Sanctuary east being open allowed chital sightings at greater distances. The census data did not indicate any diurnal variation for chital sightings (Table 24). However in the case of sambar, overall and national park evening densities were slightly higher as compared to morning values (Table 25).

6.4.2 Vehicle count winter 1988 : The density estimates of chital showed a similar trend as achieved from the previous census. However the estimates were not similar and consistent (Table 27). The overall chital density showed significant increase ($66.2 \pm 7.7/km^2$) as compared to previous census estimates. There was an overall increase in chital densities in all three units (Table 27). The sambar density also varied in different units. There was slight decrease in sambar density estimates. Sambar density decreased significantly in national park and showed a significant increase in sanctuary west ($3.2 \pm 0.73/km^2$).

The overall densities of nilgai and chowsingha also showed slight increase (Table 27). The chinkara density ($2.8 \pm 1.5/km^2$) could be estimated due to higher coverage of sanctuary east. The density estimate for chital by Kelker belt and Fourier series were higher as compared to King's method estimate. The higher chital density in national park was probably due to the coverage of areas such as Shingora Dam and Bhanej valley system which supported high chital densities. These areas were not covered in the 1987 census.

The density estimates showed significant diurnal variation for chital and sambar (Table 28 and 29). The diurnal variation was probably the result of restricted and low water availability due to drought for two consecutive years. The cervids being highly dependent on water remain in the vicinity of water holes.

6.4.3 <u>Vehicle count winter 1989</u>: The second consecutive drought ended in 1988 and there was exceptionally high rainfall (1200 mm) in Gir. There was a significant drop in the density estimates of all ungulate species. The overall chital density decreased significantly ($36.8 \pm 3.3/km^2$) and so was the case with sanctuary west and sanctuary east (28.2 ± 6 and $3.6 \pm 0.88/km^2$) respectively. However the chital density in national park decreased slightly. The overall density of sambar also decreased in sanctuary west and national park (Table 30) . The data on groups/km also showed significant drop for all species (Figure 25 and 26). There could be two probable reasons for this. Firstly there was excessive concentration in the valleys due to water scarcity during the drought years and as there was more coverage in the valley the census produced higher density estimates for all ungulate species. With an exceptionally high rainfall during monsoon 1988, the ungulate species dispersed evenly in Gir. Secondly the drought and the excessive grazing by maldharis as well as outside livestock (estimated to be 0.15 million) severely affected the grass cover in Gir. The ungulate populations fluctuated due to the environmental stress.

6.4.4 Vehicle count summer 1989: The density estimates for all ungulate species showed an upward trend during summer 1989 census. The chital density showed slight variation in all three units. Chital density showed a slight increase in overall, sanctuary west and national park values, however sanctuary east density showed a tremendous increase (Table 31) . The overall and national park sambar densities also showed slight increase during summer 1989 data (Table 32). The chital density for Gir and in three units showed significant diurnal variation (Table 34) which suggest an increased concentration of chital around the water sources in valleys. The sambar data was inadequate to show any diurnal difference during summer 1989.

6.4.5 Line transect studies :

6.4.5.1 Analysis by King's method: Data were pooled from different transects for all the three units. The angular distances were calculated by dividing the base distance with that of cosine of the sighting angles. Mean angular distance was calculated by pooling angular distances for various units. The confidence limit was calculated around the mean density achieved from individual transects. Table 40 and 41 contain density estimates for various ungulate species in different units.

Chital density reached the maximum level in sanctuary west as compared to other two units during winter 1988. The density was quite low in national park and sanctuary east. The confidence limits were quite narrow.

The chital density dropped significantly during summer 1988 in sanctuary west whereas national park and sanctuary east showed no significant change. The significant drop was a result of excessive concentration of chital population around the few artificial water holes in the western Gir. All the natural water holes had dried up during summer season. During monsoon 1988, chital density remained the same in sanctuary west whereas national park estimates showed significant increase. This increase was probably the result of excellent food and water conditions in national park during monsoon.

Sambar density was low in comparison to chital in all three strata of Gir. The density was slightly high in the national park as compared to the sanctuary west. Sambar was conspicuously absent from much of the sanctuary east area. Small sample sizes of nilgai and chinkara allowed density estimation for sanctuary east only. High confidence limits suggest that densities were highly variable on the line transects.

6.4.5.2. Analysis by "TRANSECT"

Table 36,37,38 and 39 provide chital density estimates for various strata and individual transects during different seasons. Sighting distances and sighting angles did not show any significant correlation. This ruled out the possibility of converting data into perpendicular distances and utilizing the Fourier series analysis available in program "Transect". Table 85 provides the matrix of mean sighting angle and method used for density estimation. The line transect data could only be used for chital as sightings were quite low for other ungulate species. It can be seen from the tables that chital density estimates were similar to results achieved by King's method however it should be noted that the confidence limits were not narrow and often exceeds the estimate itself. The densities are highly variable on individual transects in different strata.

6.5 DISCUSSION : Before summarising the density results achieved by the census methods used in Gir and the adequacy of various analysis procedures, it is necessary to discuss the factors which could possibly affect the census results and may cause bias in the estimates. The density estimates achieved should be as accurate as possible and precise due to their key management implications in wildlife protected areas in general and for Gir in particular as it has the only surviving populations of Asiatic lion. Trends in ungulate populations are good indicators of animal response to various management inputs and density estimates may not only be used to find out the status of populations but can also be used for the evaluation of management input. The various factors which could possibly cause bias in the density estimates in Gir can be classified in following two main categories:

(i) Sampling bias (non random distribution of ungulates as well as sampling units).

(ii)Statistical bias (skewed distribution of group size parameter).

One of the basic assumption made in line transect and other census methods is that the animals are distributed stochastically (Randomly) in space. However, this is rarely achieved in wildlife areas as many biotic and abiotic factors affect the ungulates distribution. This problem of non-random distribution of ungulate species was dealt by placing the line transects randomly in the study area. But in case of vehicle census, the existing road network was utilized which possibly may affect the density estimates. Topography plays an important role in the distribution of ungulate species. Chital for example, prefers flat areas as shown by dung density result (Chapter 5) and avoids the steep slopes. The reverse is however true for sambar. The roads in Gir mostly pass from valley and flat areas. Availability of water is yet another factor which has powerful effect on ungulates distribution in Gir. The areas which do not have water (or inadequate water) do not support higher ungulate densities. Apart from these above mentioned factors, maintenance of fire lines on both sides of roads in Gir may also have some effect on the distribution of ungulates. Continuous burning results in suppression of the shrub layer, keeping it below the browse line and also the growth of the fresh grass during late winter season. Avoidance or selection for a particular topography, uneven distribution of roads, water availability and maintenance of fire lines are some factors likely to cause sampling bias in Gir in the density estimates by vehicle counts. The densities thus achieved may be slightly higher than what one would expect under evenly distributed conditions. To explore the possibility of such sampling bias, the vehicle count data for summer 1989, was analyzed for the hills and valley areas for all three management strata. Results suggest, the chital densities do vary significantly in hilly and flat areas (Table 45). The chital density differed significantly in sanctuary west in hills and flats. This discrepancy was more obvious inside the national park and sanctuary east. The overall density estimate for chital was significantly higher in flat areas as compared to hills. There was a difference of 2890 chital between the overall estimates achieved for the three strata (48501± 5898) and the population of chital for flat (30337± 5433) and hills (15276± 312) separately.

The post facto analysis of the census data (according to hills and flat areas) supports the hypothesis that the population estimates are slightly higher. However the level of difference (2890 chital only) was not very large and may not be the basis of rejecting the density estimates. The other source of bias (statistical) in the density estimation was also explored. Mean group size of different ungulates species has been used for the calculation of individual densities. The assumption that animals are distributed randomly in space does not hold true as the individual animals in a group do not achieve random distribution. It is actually the group as a unit which achieve near random distribution and is used in the density estimation (Rodgers, 1976). The perpendicular distance is also calculated from the geometric centre of the group in line transect studies (Burnham *et al.*, 1980). The group size frequency distribution of chital was found to be positively skewed in all the four vehicle counts (Figure 24). In such a case where the distribution of a parameter is not normal, the mean does not give a correct picture of central tendency (Campbell,1989) . The use of medium group size values in the estimation of densities for different ungulate species caused a significant drop in the densities (Table 44). The total population estimate for chital dropped from 48501± 5898 to 35290± 4436 (nearly 37% drop). Similar skewed distributions for chital in group size frequencies has been observed in other wildlife areas (eg. Mishra,1982) however densities have been calculated using mean group size only (e.g. Karanth & Sunquist,1992 in Nagarahole Tiger Reserve).

The analysis of vehicle counts by three different methods produced consistent and similar results. However these results do not agree with line transect data which has produced fairly low density estimates for national park and sanctuary east. Two reasons for this disparity are inherent in sampling coverage and design of the line transects. 48 km of line transects for whole Gir as such is very low coverage and is no match for the coverage achieved by vehicle count. Distribution of transects, particularly in case of national park and sanctuary east are in low density zone and are bound to produce low densities. This is further aggravated due to limited water availability in these areas. The low sample size from line transect studies, particularly with species other than chital can not be analyzed using sophisticated computer program Transect. It can only be handled manually. This is a big limitation and these programs lose their robustness for such species. The other two methods (King's and Kelker belt) no matter how old and crude they are may handle low sample sizes of any species and considering the facilities and time available for the park managers in India, these methods are still the best. The low sample size otherwise result in poor confidence limits if analyzed by program "Transect" reducing their reliability.

If the density estimates for all ungulate species were correct for this study then chital has shown a tremendous increase since 1968. Berwick (1974) reported chital density as 3.57/ km^2 for whole of Gir during the hot dry season of 1970. The density of chital increased by 1000% in 21 years duration (according to summer 1989 census using medium group size values). The obvious question which arises here is whether this increase is possible biologically in a wild ungulate population and if so what are the factors which have led to this tremendous increase despite the presence of several decimation factors such as increased predation pressure from lions and leopards, presence of domestic livestock and to some extent poaching which has been controlled during eighties. It has been estimated that large predators crop 10-20 % of the annual increment of the prey species (Karanth, 1988; Johnsingh, 1983). Considering the level of predation on chital population in Gir, the increase is well within the limits of biological capacity of the chital population.

Berwick (1974) ruled out the possibility of ungulate populations being regulated by poaching, disease and forage competition with domestic livestock in Gir. He considered predation by lions and leopards as the sole factor in regulating the ungulate populations in Gir.

Joslin (1973) investigated food habits of lions in Gir and found domestic livestock comprised 75% diet. The rest of 25% was accounted for by wild ungulate. In 1972, Gujarat Forest Department started a programme of shifting the maldharis and their domestic livestock and as a result, out of 129 nesses 57 nesses were resettled out side. The entry of migratory cattle have also been controlled. The shifting of maldharis from Gir and reduced entry of outside cattle, would certainly have resulted in low livestock density or in other words reduced food availability for lion in Gir as livestock dominated the diet of lions. Recently Sinha (1987) and Chellam (1986 onwards) have also shown that major portion of lions diet is formed by wild animals (65% wild ungulate with some spatio-temporal variation in overall diet). If predation was the sole factor regulating herbivore population in 1970s then how can the chital population show such tremendous increase despite the fact that predation has also increase tremendously? The presence of excessive maldharis domestic livestock, a large number of migratory cattle and poaching must have had some role in the population regulation of wild ungulates in Gir. The subsequent removal of cattle may have resulted in greater feeding resources for chital populations through gradual increase in forage production and access to the optimum habitats which were occupied by the domestic livestock. The dung density data (Chapter 5) do suggest a depressive effect of domestic livestock on chital population.

The presence of remaining cattle acted as buffer to cause the eruption of chital populations in Gir. The domestic livestock still contribute significantly to the lions diet in west Gir and totally dominate in eastern Gir.

The densities of other ungulate species i.e.sambar, nilgai, chowsingha and chinkara have not shown any substantial increase in densities and have probably gone down in case of nilgai and wild boar. As far as sambar population is concerned the predation pressure is quite high in Gir and the removal of livestock may not have benefitted the sambar as it occupies the hilly terrain and is a mixed feeder with year round dominance of browse in diet. The population of sambar may still be under the predator sink which does not allow it to grow rapidly in Gir.

There are several differences in the census methods used by Berwick (1974) and the method used in this study. Firstly counts were conducted by Berwick (1974) during day and nights and high number of sightings were used for the analysis. It has been observed that there are significant differences in day and night congregations of chital in Bandipur (Sharatchandra and Gadgil, 1975) and inclusion of night count data in density analysis must have caused some bias. Secondly the widths used in the analysis were 128 m for day time and 100 m during night time. The width used was too big and the ungulate populations were probably underestimated. The fixed width of 128 m if used for the analysis of summer 1989 data for chital produces a density of 9.2 chital/ km^2 which would be a gross underestimation of the actual densities of chital in Gir.

Gir supports a much higher ungulate biomass (kg/ km^2) compared to the seventies. Gir supported 6342.9 kg/km^2 of ungulate biomass in 1970. The domestic livestock contributed 97.3% to it and Gir now supports much higher biomass of wild ungulates. The biomass was highest in sanctuary east (10607.6 kg/km^2) as compared to the sanctuary west (6246.8 kg/km^2) and national park (1818kg/km^2). The biomass has been calculated using the median group size values for summer 1989 census. The biomass estimation for domestic livestock is in a way under estimation as outside cattle from nearly 72 villages on the periphery of Gir have not been included. These biomass figures suggest that national park and sanctuary east still have potential to support greater wild ungulate biomass if carefully managed. The densities of these ungulate species and the biomass figures from Gir may be compared with other protected areas in Indian subcontinent and elsewhere. The overall density of chital for Gir according to vehicle census summer 1989 (using mean group size values to make comparison valid) was 48.1 chital/km^2 which was similar to Nagarahole Tiger Reserve (NTR) (50.6 chital/km^2, Karanth and Sunquist, 1992). The chital density from Gir was much higher than Bandipur Tiger Reserve(BTR) (40 chital /km^2, Johnsingh, 1983), Kanha National Park(KNP)(3.2 chital/km^2, Schaller, 1967), Wilpattu National Park (WNP)(5.8/km^2, Eisenberg and Lockhart,1972), Royal Karnali Bardia Reserve (RKBR) (32.8 chital/km^2 , Dinerstein, 1980) and Chitwan National Park (CNP) (16.8 chital/km^2 , Tamang, 1982). The overall sambar density for Gir (0.93 sambar/km^2) was similar to KNP only (0.9 sambar/km^2, Schaller,1967) and was lower than NTR (5.5/km^2, Karanth and Sunguist, 1992), BTR (0.7 sambar/km^2, Johnsingh, 1983), WNP (5.8 sambar/km^2, Eisenberg and Lockhart ,1972), RKBR(3.5 sambar/km^2, Dinerstein,1980), and CNP (2.7 sambar/km^2, Tamang, 1982). The nilgai density in Gir (0.30 nilgai/km^2) was lower than Keoladeo National Park (Haque, 1990). However this comparison should be viewed cautiously due to the differences in methodologies adopted by different workers, sampling sizes, difference in analysis procedure and observers bias.

The overall biomass of wild ungulate in Gir was 1895.6 kg/km^2. The biomass was higher than KTR (1592 kg/km^2), WNP (766 kg/km^2), but was lower than NTR(14744 kg/km^2), BTR (14520 kg/km^2), RKBR (3101 kg/km^2) and CNP (2581 kg/km^2). Several workers (e.g. Haque, 1990; Karanth and Sunquist, 1992) have so far attempted a similar comparison of biomass figures between different wildlife areas. However such a comparison is quite misleading due to the fact that there is a time gap in most of the studies and areas differ in terms of number of species they contain. For instance, Haque (1990) while comparing wild ungulate biomass of Keoladeo National Park (KNP) with that of Gir states that the density and biomass of chital and sambar in Keoladeo National Park was comparatively lower than other parks except Gir where it exceeds. This is simply an artefact resulting due to the time leg between the two studies. The present biomass of chital and sambar in Gir (1585$\pm$ 199 kg/km^2 and 66.4 kg/km^2) is higher than KNP where the biomass of chital and sambar was 461.2 kg/km^2 and 128.6 kg/km^2 respectively. Similarly the higher biomass figures from NTR (14744 kg/km^2) and BTR (14520 kg/km^2) are due to the presence of megaherbivores like elephants and bison and if at all a comparison is made, it should be done for specific species only rather than for whole ungulate assemblage in a protected area.

Table 20. Herbivore densities in Gir National Park and Sanctuary (Density number per sq km). Vehicle count, Summer 1987.

Chital

	King Census		Kelker Belt	
Stratum	Pooled Data	Individual Transects	Pooled Data	Individual Transects
Overall	53.2	54.5 ±10.03	49.3	49.9 ±9.6
S.W.	68.8	71.1 ±14.2	65.7	64.3 ±14.1
N.P.	38.3	39.9 ±6.9	34.9	35.0 ±7.4
S.E.	38.4	29.1 ±15.5	32.1	32.8 ±19.1

Sambar

	King Census		Kelker Belt	
Stratum	Pooled Data	Individual Transects	Pooled Data	Individual Transects
Overall	3.1	6.5 ±3.5	2.1	3.1 ±1.4
S.W.	1.5	1.3 ±0.7	0.84	1.2 ±0.3
N.P.	5.7	7.4 ±3.1	4.1	6.5 ±2.6
S.E.	0	0 0	0	0 0

Stratum	Nilgai	Chowsingha	Wild boar
Overall	.51	.82	.65

Table 21. Density estimate of Chital by Fourier series estimator (Grouped data). Vehicle count, Summer 1987.

Stratum	Density	S.E.	% Coeff. of Var.	95% C.L.
Overall	51.45	2.5	2.5	±4.95
S.W.	63.45	3.5	31.5	±7.8
N.P.	45.4	3.75	41.5	±7.4
S.E.	20.35	5.05	124.5	±9.95

Table 22. Density estimates of Sambar by Fourier series estimator (Grouped data). Vehicle count, Summer 1987.

Stratum	Density	S.E.	% Coeff. of Var.	95% C.L.
Overall	3.06	0.40	22.1	+0.68
S.W.	1.2	0.44	60.01	+0.90
N.P.	5.9	0.88	25.16	+1.7

Table 23. Density estimates of Chowsingha by Fourier series estimator (Grouped and truncated data). Vehicle count, Summer 1987.

Stratum	Animal	Density	S.E.	% Coeff. of Var.	95% C.L.
Overall	Chowsingha	0.85	0.19	26.2	±0.40

Table 24. Chital density diurnal variation. Density estimated by Fourier series estimator (Grouped and truncated data). Vehicle count, Summer 1987.

Stratum	Time	Density	S.E.	% Coeff.of Var.	95% C.L.
Overall	A.M.	53.136	3.5	31.6	±7.05
Overall	P.M.	53.8	3.6	35.3	±7.5
S.W.	A.M.	71.2	6.8	51.9	±13.6
S.W.	P.M.	71.6	6.4	52.38	±13.6
N.P.	A.M.	37.3	4.4	51.3	±9.2
N.P.	P.M.	40.4	4.6	47.1	±9.6
S.E.	A.M.	0	0	0	0
S.E.	P.M.	37.4	11.76	276.3	±24.36

Table 25. Sambar density diurnal variation. Density estimation by Fourier series estimator (Grouped and truncated data). Vehicle count, Summer 1987.

Stratum	Time	Density	S.E.	% Coeff.of Var.	95% C.L.
Overall	A.M.	2.5	0.56	35.3	±0.95
Overall	P.M.	3.23	0.68	34.6	±1.3
S.W.	A.M.	1.34	0.72	108	±1.2
S.W.	P.M.	0.72	0.47	90.5	±0.81
N.P.	A.M.	4.3	1.04	37.7	±2.08
N.P.	P.M.	7.74	1.6	39.06	±3.2
S.E.	A.M.	0	0	0	0
S.E.	P.M.	0	0	0	0

Table 26. Herbivore densities in Gir. Vehicle count, Winter 1988.

Chital

Stratum	King Census: Pooled Data	King Census: Individual Transects		Kelker Belt: Pooled Data	Kelker Belt: Individual Transects	
Overall	55.6	59.8	±11.7	66.27	67.5	±159
S.W.	70.0	74.2	±16.5	70.2	70.1	±203
N.P.	56.0	57.5	±16.5	71.3	84.8	±365
S.E.	29.9	30.1	±11.5	36.07	44.0	±169

Sambar

Stratum	King Census: Pooled Data	King Census: Individual Transects		Kelker Belt: Pooled Data	Kelker Belt: Individual Transects	
Overall	2.1	3.2	±1.5	2.8	2.6	±15
S.W.	2.2	3.6	±1.7	2.5	2.4	±14
N.P.	2.8	4.4	±4.2	5.1	4.2	±39
S.E.	0.52	0.47	±0.65	0.35	0.14	±027

Nilgai

Stratum	Overall	S(West)	N.P.	S(East)
Density	1.02	1.3	0.94	1.6

Stratum	Animal species	Density
Overall	Chowsingha	0.73
Overall	Wild boar	0.91
S.E.	Chinkara	3.3

Table 27. Density estimate of Chital by Fourier series estimator (Grouped and truncated data). Vehicle count, Winter 1988.

Stratum	Density	S.E.	% Coeff. of Var.	95% C.L.
Overall	66.24	3.96	27.0	±7.7
S.W.	72.3	4.9	33.3	±10.4
N.P.	73.4	6.72	43.6	±13.2
S.E.	31.2	3.9	50.4	±7.7

Sambar

Stratum	Density	S.E.	% Coeff. of Var.	95% C.L.
Overall	1.96	0.27	26.2	±0.55
S.W.	3.2	0.72	42.1	±0.73
N.P.	1.96	0.55	55.08	±1.1

Stratum	Animal	Density	S.E.	% Coeff.of Var.	95% C.L.
Overall	Chowsingha	1.09	0.22	33.9	±0.48
Overall	Nilgai	1.2	0.23	40.5	±0.46
S.E.	Chinkara	2.8	0.79	46.9	±1.5

Table 28. Chital density diurnal variation. Density estimated by Fourier series estimator (Grouped and truncated data). Vehicle count, Winter 1988.

Stratum	Time	Density	S.E.	% Coeff.of Var.	95% C.L.
Overall	A.M.	51.48	4.2	37.8	±13.2
Overall	P.M.	77.4	5.4	32.8	±11.2
S.W.	A.M.	63.9	7.3	54.2	±14.7
S.W.	P.M.	76.9	7.2	42.3	±14.4
N.P.	A.M.	40.8	9.03	96.3	±18.06
N.P.	P.M.	83.52	7.6	44.16	±14.8
S.E.	A.M.	0	0	0	0
S.E.	P.M.	38.4	5.2	53.7	±10.02

Table 29. Sambar density diurnal varition. Density estimation by Fourier series estimator (Grouped and truncated data). Gir vehicle count, Winter 1988.

Stratum	Time	Density	S.E.	% Coeff.of Var.	95% C.L.
Overall	A.M.	1.08	0.44	70.7	±0.90
Overall	P.M.	3.96	0.81	36.5	±1.6
S.W.	A.M.	1.6	0.70	68.3	±1.3
S.W.	P.M.	5.04	1.3	48.4	±2.7
N.P.	A.M.	0.81	1.5	161.4	±1.3
N.P.	P.M.	4.6	1.5	62.8	±2.7
S.E.	A.M.	0	0	0	0
S.E.	P.M.	0	0	0	0

Table 30. Density estimate of Chital by Fourier series estimator (Grouped data). Vehicle count, Winter 1989.

Stratum	Density	S.E.	% Coeff. of Var.	95% C.L.
Overall	36.8	1.8	33.5	±3.3
S.W.	28.2	1.7	41.4	±6.0
N.P.	65.5	4.9	58.5	±9.3
S.E	3.6	4.1	672.6	±0.88

Stratum	Density	S.E.	% Coeff. of Var.	95% C.L.
Overall	0.25	0.16	99.0	±0.18
S.W.	0.63	0.22	51.8	±0.46
N.P.	0.14	0.50	46.3	±0.11

Nilgai

Stratum	Density	S.E.	% Coeff. of Var.	95% C.L.
Overall	1.4	1.06	152.2	±0.72

Table 31. Density estimate of Chital by Fourier series estimator (Grouped data). Vehicle count, Summer 1989.

Stratum	Density	S.E.	% Coeff. of Var.	95% C.L.
Overall	48.1	2.99	40.95	±5.85
S.W.	48.7	4.5	52.64	±8.9
N.P.	39.6	3.1	53.4	±6.2
S.E.	52.1	4.6	64.6	±8.8

Table 32. Density estimates of Sambar by Fourier series estimator. (Grouped and truncated data). Vehicle count, Summer 1989.

Stratum	Density	S.E.	% Coeff. of Var.	95% C.L.
Overall	0.93	0.18	34.9	±0.36
N.P.	1.8	0.42	40.29	±0.85

Table 33. Density estimates of Chowsingha by Fourier series estimator (Grouped and truncated data). Vehicle count, Summer 1989.

Stratum	Animal	Density	S.E.	% Coeff.of Var.	95% C.L.
Overall	Nilgai	0.36	0.02	31.08	±0.19
S.E.	Chinkara	3.00	0.80	64.00	±1.4

Table 34. Chital density diurnal variation. Density estimated by Fourier series estimator (Grouped and truncated data). Gir vehicle count, Summer 1989.

Stratum	Time	Density	S.E.	% Coeff.of Var.	95% C.L.
Overall	A.M.	46.9	2.9	35.2	±6.05
Overall	P.M.	57.02	4.02	49.9	±6.6
S.W.	A.M.	39.9	4.7	53.7	±9.6
S.W.	P.M.	32.2	8.06	162.4	±16.7
N.P.	A.M.	51.0	4.5	52.8	±8.4
N.P.	P.M.	58.03	6.4	79.9	±12.6
S.E.	A.M.	60.3	8.54	91.5	±17.6
S.E.	P.M.	54.02	15.09	206.4	±29.6

Table 35. Sambar density diurnal variation. Density estimation by Fourier series estimator (Grouped and truncated data). Gir vehicle count, Summer 1989.

Stratum	Time	Density	S.E.	% Coeff.of Var.	95% C.L.
Overall	A.M.	0.75	0.23	55.4	±0.48
Overall	P.M.	1.2	0.32	45.9	±0.64
S.W.	A.M.	0	0	0	0
S.W.	P.M.	0	0	0	0
N.P.	A.M.	0.84	0.43	77.4	±0.81
N.P.	P.M.	2.7	0.88	58.6	±1.7
S.E.	A.M.	0	0	0	0
S.E.	P.M.	0	0	0	0

Table 36. Density of Chital in various strata and transects, Winter 1988.

Stratum	Density	S.E.	%Coeff. of Var.	95% C.L.
S.W.	71.8	10.3	72.9	±20.1
N.P.	9.8	4.9	181.3	±9.8
S.E.	1.6	1.2	267.8	±2.1

Transect	Density	S.E.	% Coeff. of Var.	95% C.L.
Raidi	96.2	17.1	17.9	±33.5
Kadeli	63.9	13.7	108.1	±27.6
Panvi	35.8	12.1	172.8	±24.2

Methods specified in data matrix.

Table 37. Density of Chital in various strata and transects, Summer 1988.

Stratum	Density	S.E.	% Coeff. of Var.	95% C.L.
S.W.	14.0	3.1	79.1	±6.3
N.P.	12.7	4.1	93.1	±8.1
S.E.	7.2	4.3	228.2	±8.9

Transect	Density	S.E.	% Coeff. of Var.	95% C.L.
Raidi	17.85	7.2	139.6	±14.0
Kadeli	17.02	8.5	173.06	±16.6
Panvi	11.04	6.4	266.8	±12.8
Ambla	12.4	5.4	145.6	±11.0
Junwania	14.0	8.0	144.0	±16.0
Rajsthali	7.2	4.3	228.2	±8.9

Methods specified in data matrix.

Table 38. Density of Chital in various strata and transects, Monsoon 1988.

Stratum	Density	S.E.	% Coeff. of Var.	95% C.L.
S.W.	13.7	3.9	151.1	±7.9
N.P.	21.2	9.1	327.5	±17.9
S.E.	0	0	0	0

Transect	Density	S.E.	% Coeff. of Var.	95% C.L.
Raidi	9.1	3.7	200.0	±6.9
Kadeli	39.06	22.6	371.7	±45.3
Panvi	19.3	11.9	352.2	±23.3
Ambla	8.3	4.4	273.0	±8.8
Junwania	31.8	16.3	438.6	±31.8

Methods specified in data matrix.

Table 39. Density of Chital in various strata and transects, Winter 1989.

Stratum	Density	S.E.	% Coeff. of Var.	95% C.L.
S.W.	39.7	6.9	85.5	±14.2
N.P.	X	X	X	X
S.E.	X	X	X	X

Transect	Density	S.E.	% Coeff. of Var.	95% C.L.
Raidi	23.2	6.45	125.9	±13.3
Kadeli	39.5	12.9	116.9	±29.6
Panvi	82.6	18.1	147.4	±35.2
Ambla	X	X	X	X
Junwania	X	X	X	X
Rajsthali	X	X	X	X

X Data not amenable to analysis.

Methods specified in data matrix.

Table 40. Seasonal variation in density of Chital and Sambar in different strata in 1987-88 by King census method.

		S(West)		N.P.		S(East)	
Animal	Season	n	Density	n	Density	n	Density
Chital	Winter'87-88	17	60.8 $\pm$14.8	11	8.5 $\pm$4.4	5	6.4 $\pm$23
	Summer'88	13	13.2 $\pm$6.9	6	10.5 $\pm$5.3	4	8.3 $\pm$81
	Monsoon'88	18	11.5 $\pm$4.5	8	19.4 $\pm$12.0	-	--
Sambar	Winter'87-88	17	2.4 $\pm$2.5	11	3.7 $\pm$1.3	-	--
	Summer'88	13	2.7 $\pm$0.9	6	2.3 $\pm$0.8	-	--
	Monsoon'88	18	1.9 $\pm$1.1	8	4.7 $\pm$3.1	-	--

Table 41. Seasonal variation in Chinkara & Nilgai densities in Eastern Gir. King Census Method, Winter & Summer 1988.

Stratum	Animal	Density	Season
S.E.	Chinkara	3.5 ±6.04	Winter
S.E.	Nilgai	3.9 ±5.01	Winter
S.E.	Chinkara	1.5 ±0.09	Summer
S.E.	Nilgai	4.0 ±5.6	Summer

Table 42. Biomass estimates for different species in different strata based on Fourier series estimates of vehicle count, Winter 1989 (using Median Group Size values).

Stratum	Animal species	Unit weight*	Density	Biomass per km^2
Overall	Chital	45.3	35.0 $\pm$4.4	1585.5$\pm$1993
Gir(West)	Chital	45.3	43.0 $\pm$7.9	1947.9$\pm$3578
N.P.	Chital	45.3	30.0 $\pm$4.6	1359.0$\pm$2080
Gir(East)	Chital	45.3	36.5 $\pm$6.1	1653.4$\pm$2763
Overall	Sambar	166.0	1.03 $\pm$0.4	170.9$\pm$ 664
N.P.	Sambar	166.0	2.1 $\pm$1.0	348.6$\pm$1660
Overall	Nilgai	184.0	0.6 $\pm$0.31	110.4 $\pm$570
Gir(East)	Chinkara	12.0	2.4 $\pm$1.1	28.8 $\pm$132
Gir(West)	Domestic buffalo	410.0	9.8	4018.0
Gir(East)	Domestic buffalo	410.0	21.56	8815.0
Gir(West)	All species	--	--	6246.8
N.P.	All species	--	--	1818.0
Gir(East)	All species	--	--	10607.6

* Berwick & Jordon (1971), Berwick (1974).

Table 43. Percentage contribution of different herbivore species in total biomass estimates (kg per sq km) in different strata of Gir.

		Percent					
Stratum	Biomass	Chital	Sambar	Nilgai	Chowsingha	Chinkara	D.L.
Gir(W)	6246.8	31.1	2.7	1.7	--	--	64.3
N.P.	1818.0	74.7	19.1	6.07	--	--	--
Gir(E)	10607.6	15.5	--	1.04	--	0.27	83.1

Table 44. Total population size of different ungulate species in Gir (vehicle count, Summer 1989)

Stratum	Animal species	Density	Area censused	Total population Mean Group Size	Total population Median Group Size
Overall	Chital	48.1 ± 5.8	1008.34	48501.1 ± 5898.7	35290 ± 4436
Sanctuary (West)	Chital	48.7 ± 8.9	489.7	23848.3 ± 4358.3	21057 ± 3868
National Park	Chital	39.6 ± 6.2	258.7	10244.5 ± 1603.9	7761 ± 1190
Sanctuary (East)	Chital	52.1 ± 8.8	262.9	13697.0 ± 2313.5	9595 ± 1603
Overall	Sambar	0.93 ± 0.36	1008.34	937.7 ± 362.9	1038 ± 403
National Park	Sambar	1.8 ± 0.85	258.7	465.6 ± 219.8	543 ± 258
Overall	Nilgai	0.36 ± 0.19	1008.34	363.0 ± 191.5	605 ± 312
Sanctuary (East)	Chinkara	3.0 ± 1.4	262.9	788.7 ± 368.0	630 ± 288

Table 45. Vehicle census for Chital. Summer 1989 (post facto stratification).

	Sanctuary West		National Park	
	Flat	Hill	Flat	Hill
Area (sq km)	243.75	261.5	105.75	153.25
Median group size	5	3	6	3
Density	35.3±6	22.2±6.6	57.9±9	10.6±3.6
Total Population	8,603 ±1,462.2	5,805 ±1,725.9	6,120 ±951.3	1,627 ±5515

	Sanctuary East		Overall	
	Flat	Hill	Flat	Hill
Area (sq km)	100.75	186.75	450.25	601.5
Median	5	4	5	4
Density	90.5±19	16.8±7.6	47.5±8.5	21.2±4.4
Total Population	9,095 ±1,907.6	3,137 ±1,418.9	21,380 ±3,826.7	12,750 ±2,646.6

Fig.15 DISTRIBUTION PATTERN OF CHITAL IN GIR LION SANCTUARY & NATIONAL PARK GUJARAT, (GIR VEHICLE COUNT WINTER 1988).

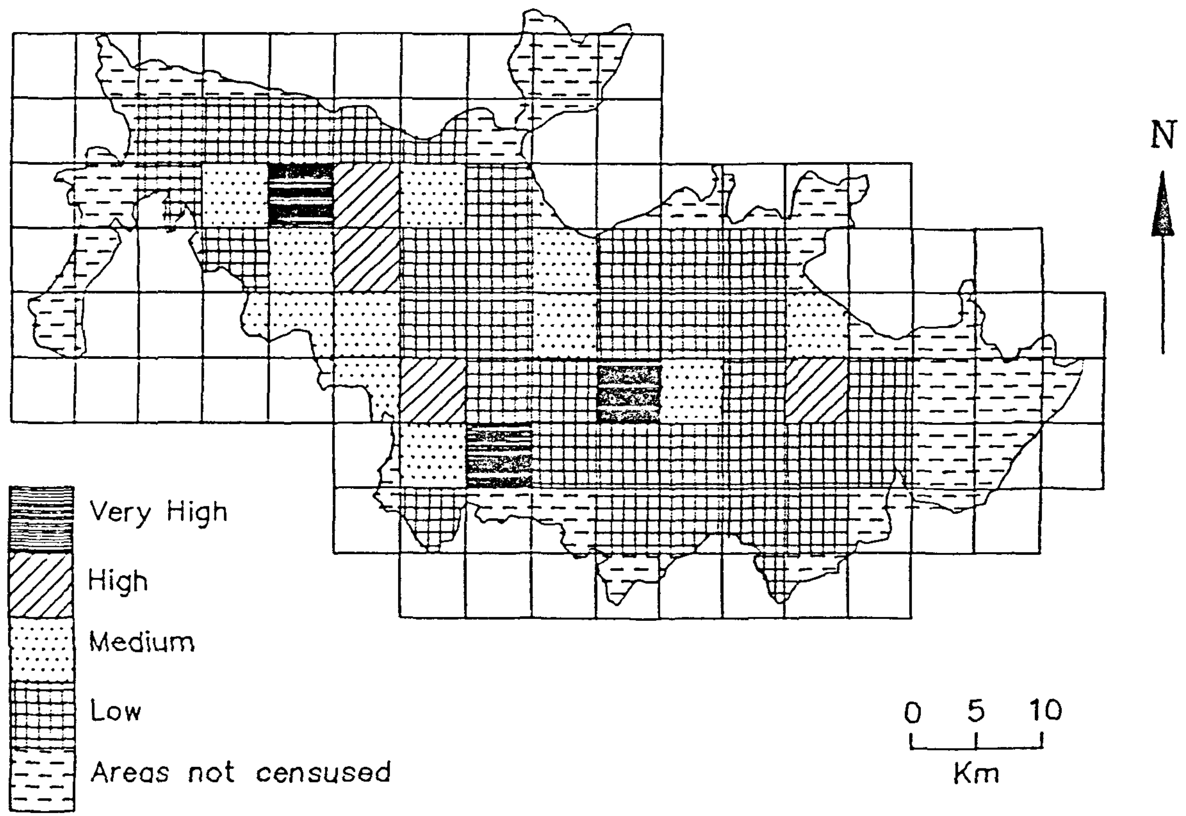


Fig.16 DISTRIBUTION PATTERN OF SAMBAR IN GIR LION SANCTUARY & NATIONAL PARK GUJARAT, (GIR VEHICLE COUNT WINTER 1988).

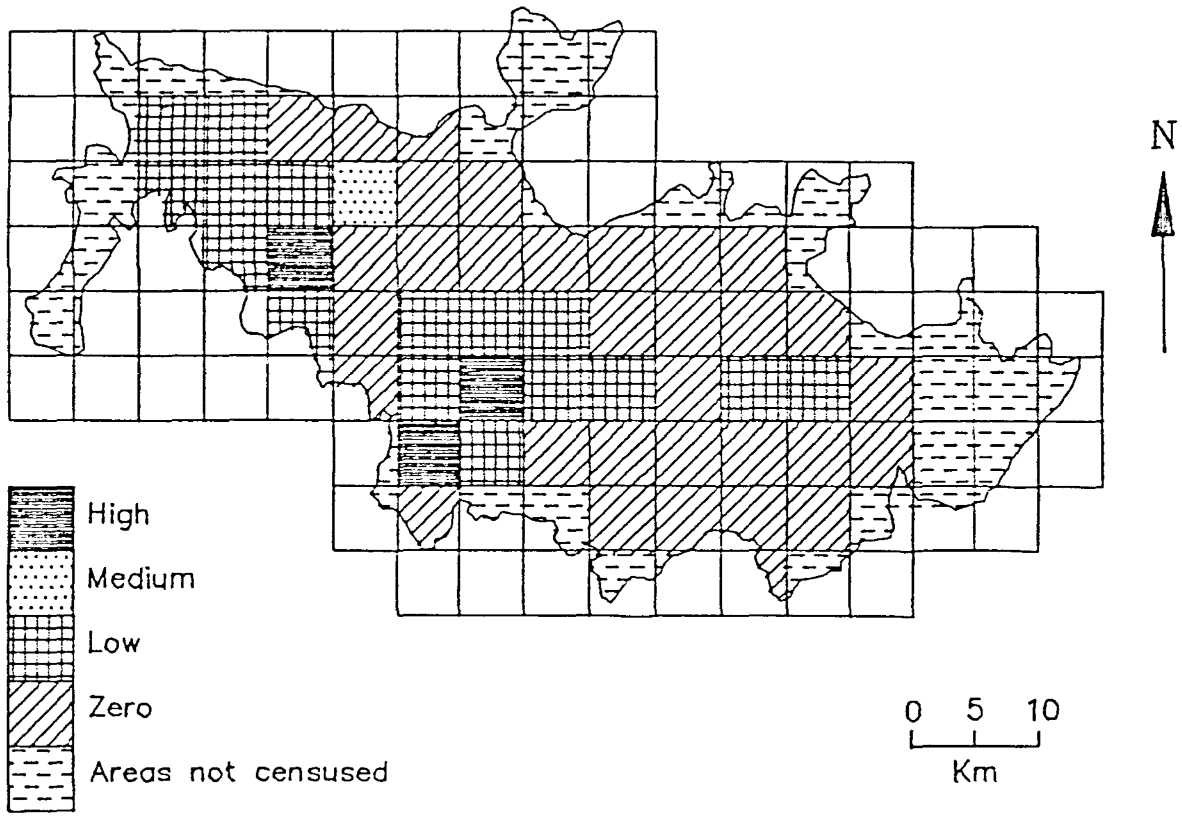


Fig.17 DISTRIBUTION PATTERN OF CHINKARA IN GIR SANCTUARY & NATIONAL PARK GUJARAT, (GIR VEHICLE COUNT WINTER 1988).

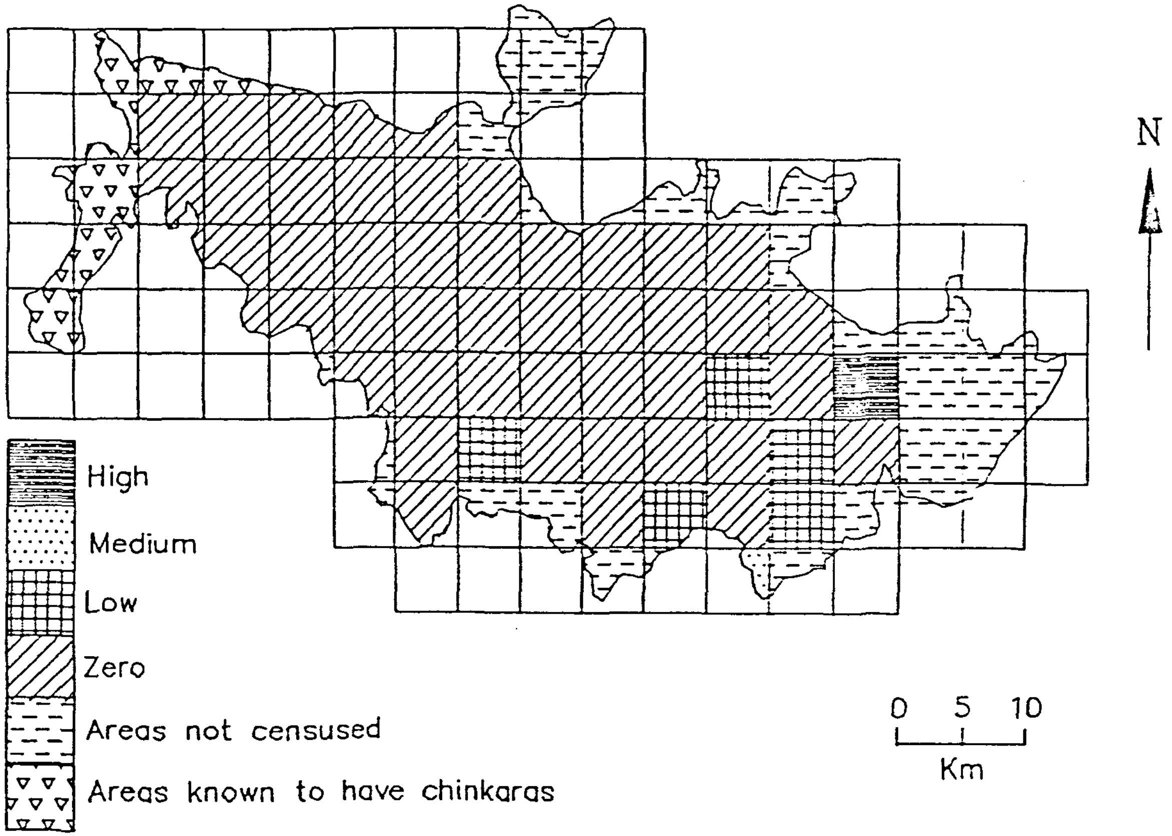
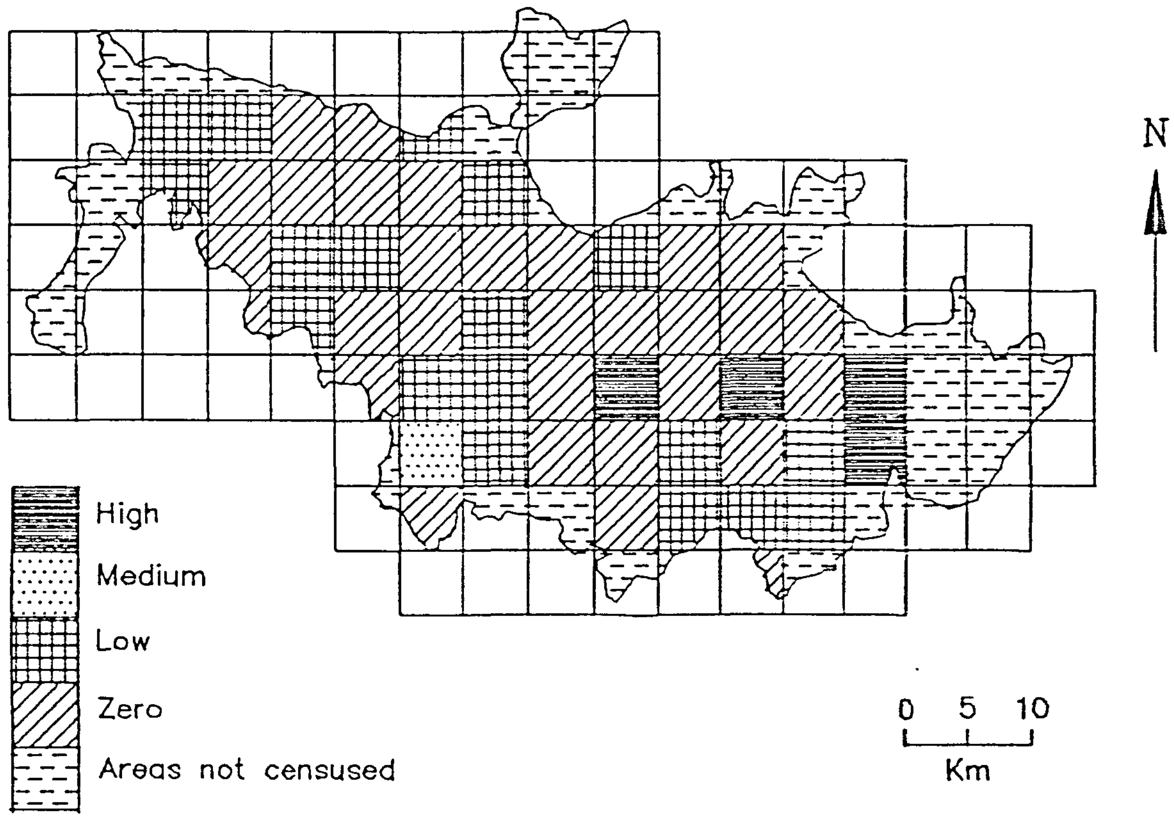


Fig.18 DISTRIBUTION PATTERN OF NILGAI IN GIR SANCTUARY & NATIONAL PARK GUJARAT, (GIR VEHICLE COUNT WINTER 1988).



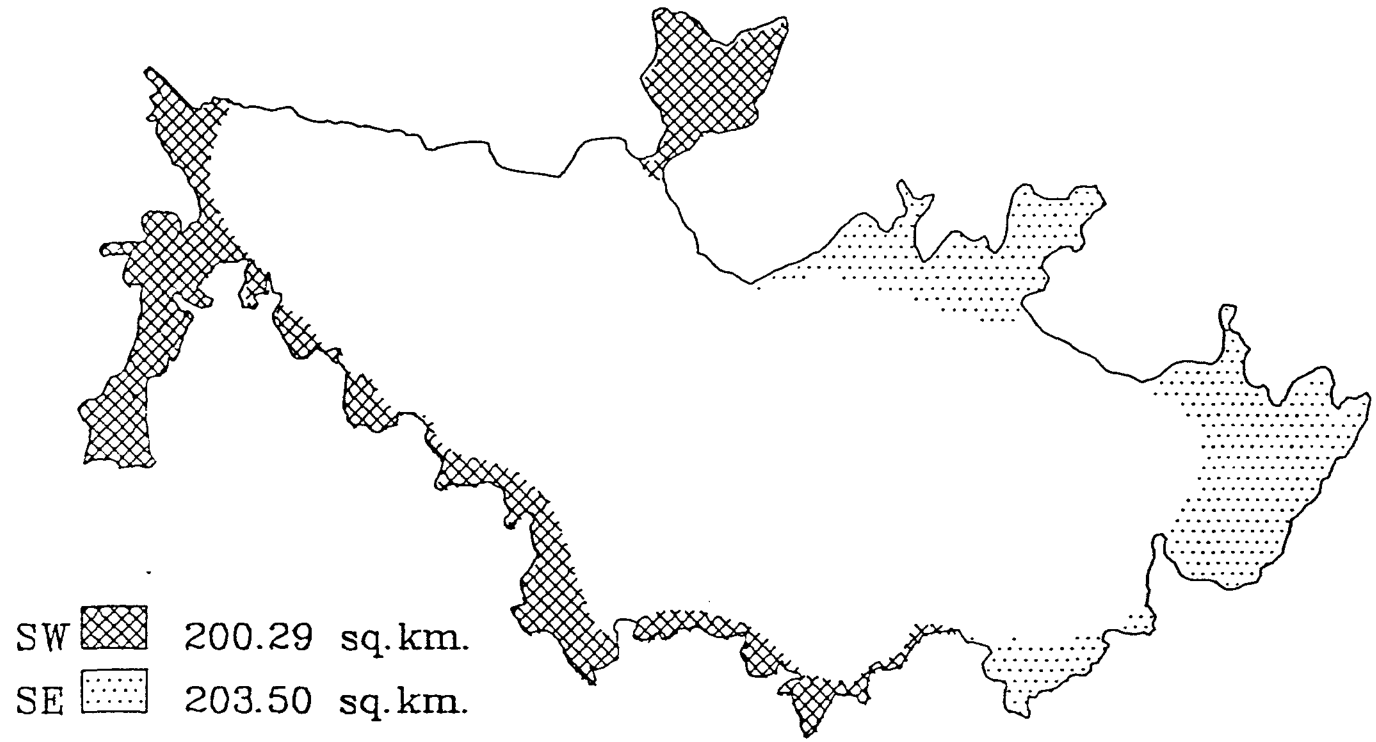


Fig.19 Areas Excluded From Total Population Estimation of Herbivores in Gir

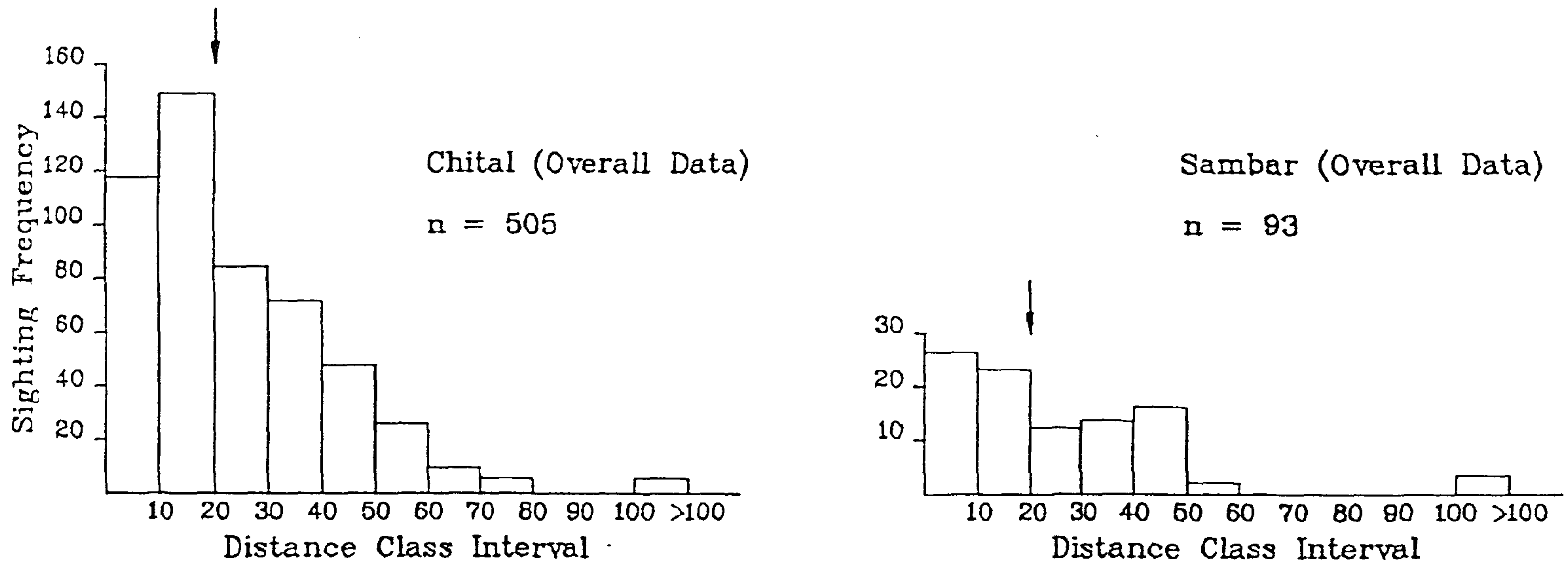


Fig.20 DETERMINATION OF ESW BY KELKER BELT METHOD (GIR VEHICLE COUNT, 1987).

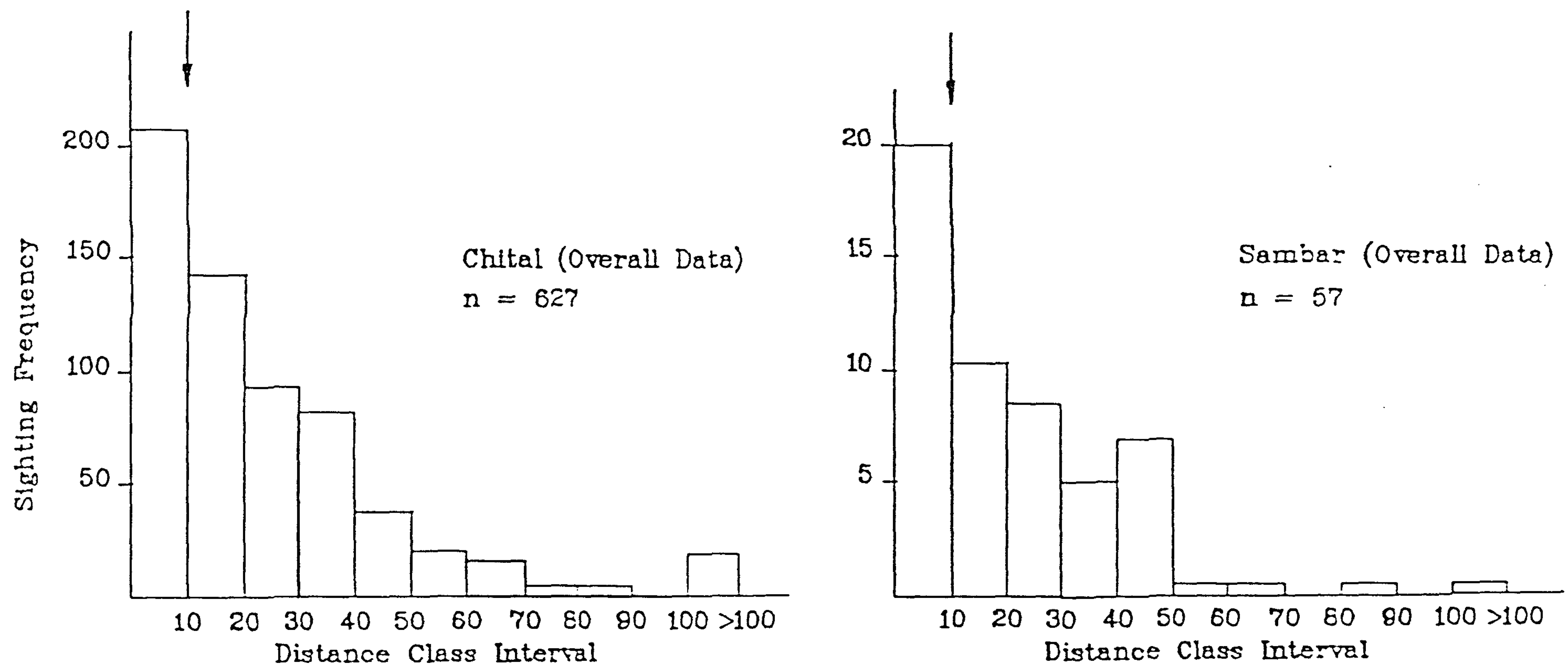


Fig. 21 DETERMINATION OF ESW BY KELKER BELT METHOD (GIR VEHICLE COUNT WINTER, 1988)

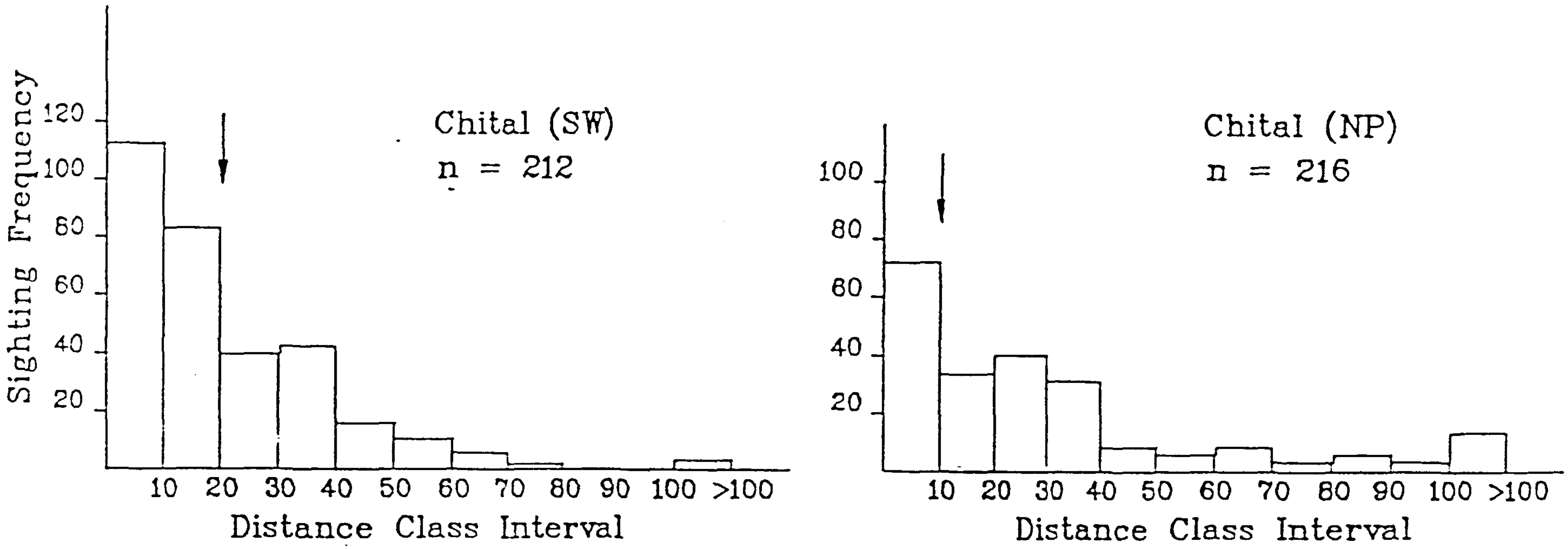


Fig. 22.DETERMINATION OF ESW BY KELKER BELT METHOD (GIR VEHICLE COUNT WINTER, 1988)

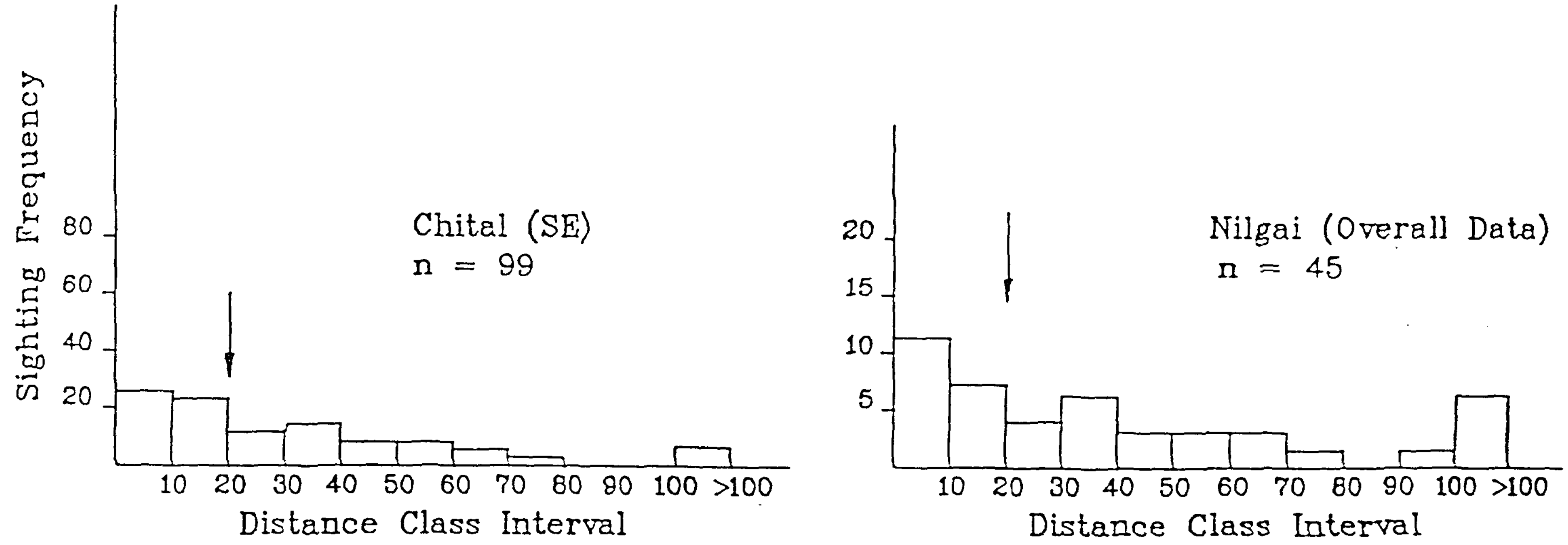
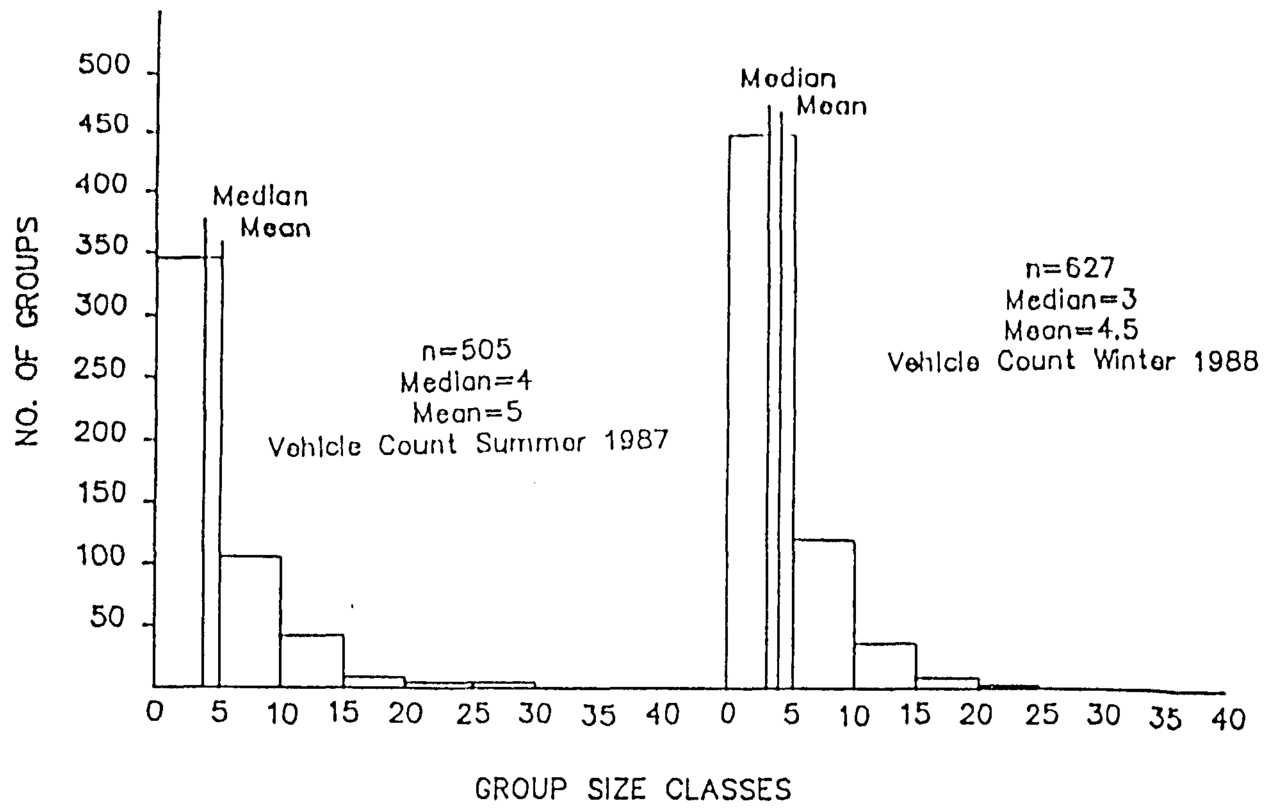


Fig. 23. DETERMINATION OF ESW BY KELKER BELT METHOD (GIR VEHICLE COUNT WINTER, 1988)



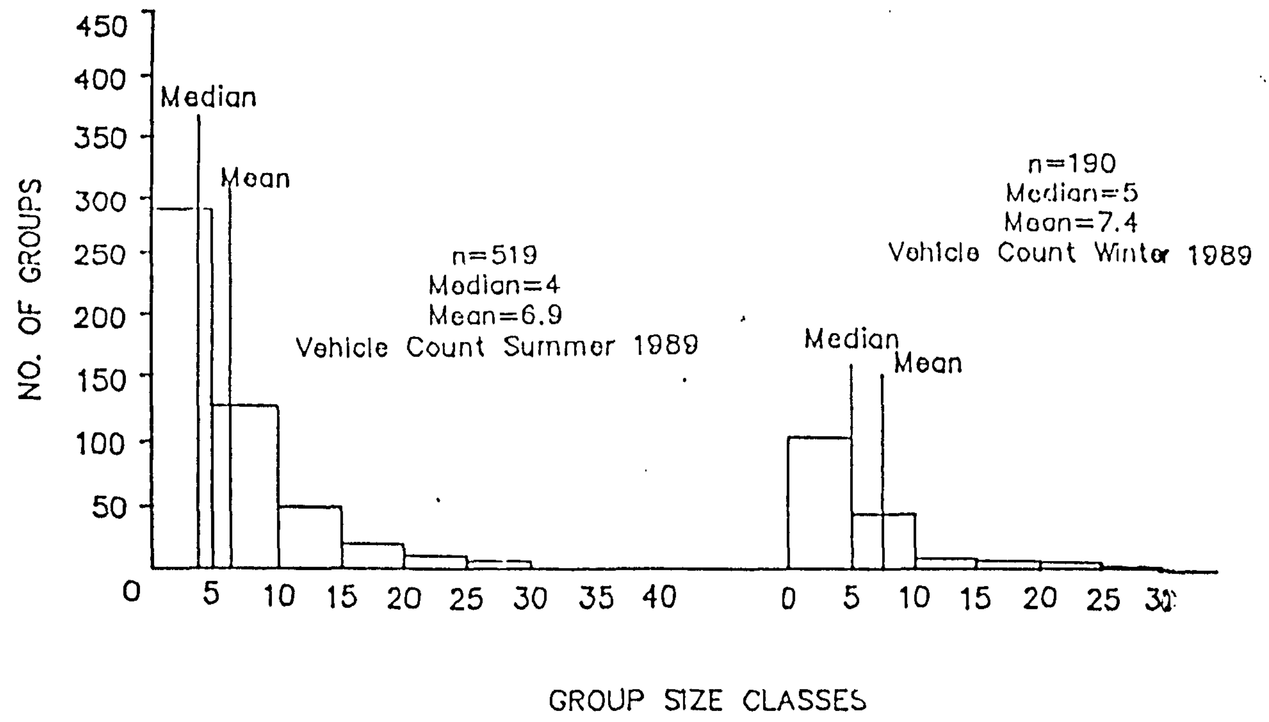


Fig. 24 : Group size class frequencies, median and mean values of chital during different vehicle censuses.

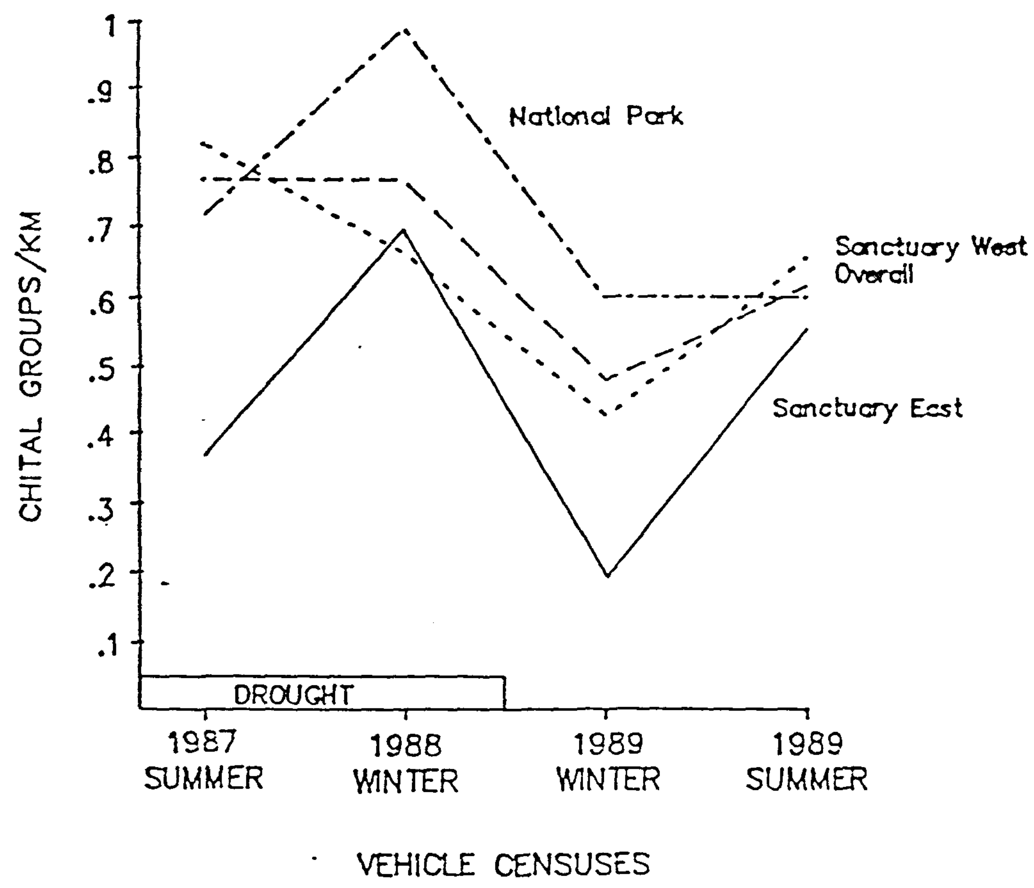


Fig. 25: Number of chital groups/km during different vehicle censuses.

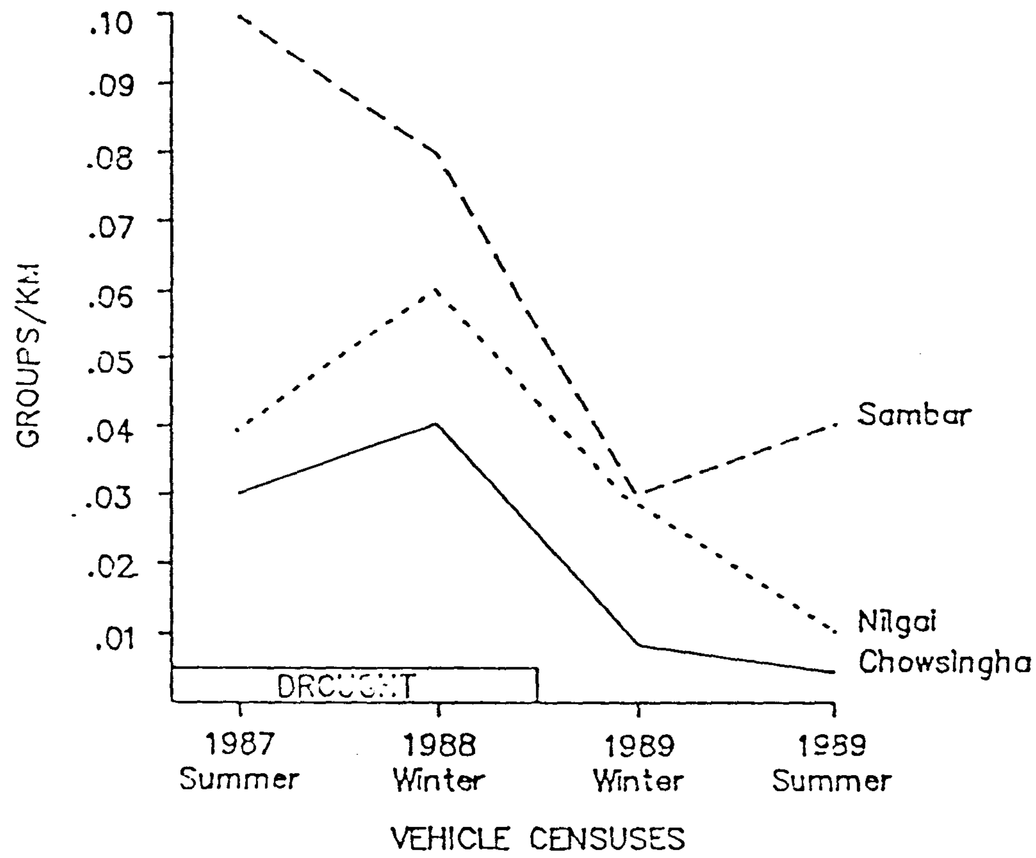


Fig. 26: No. of groups/km for different herbivore species during different vehicle censuses.

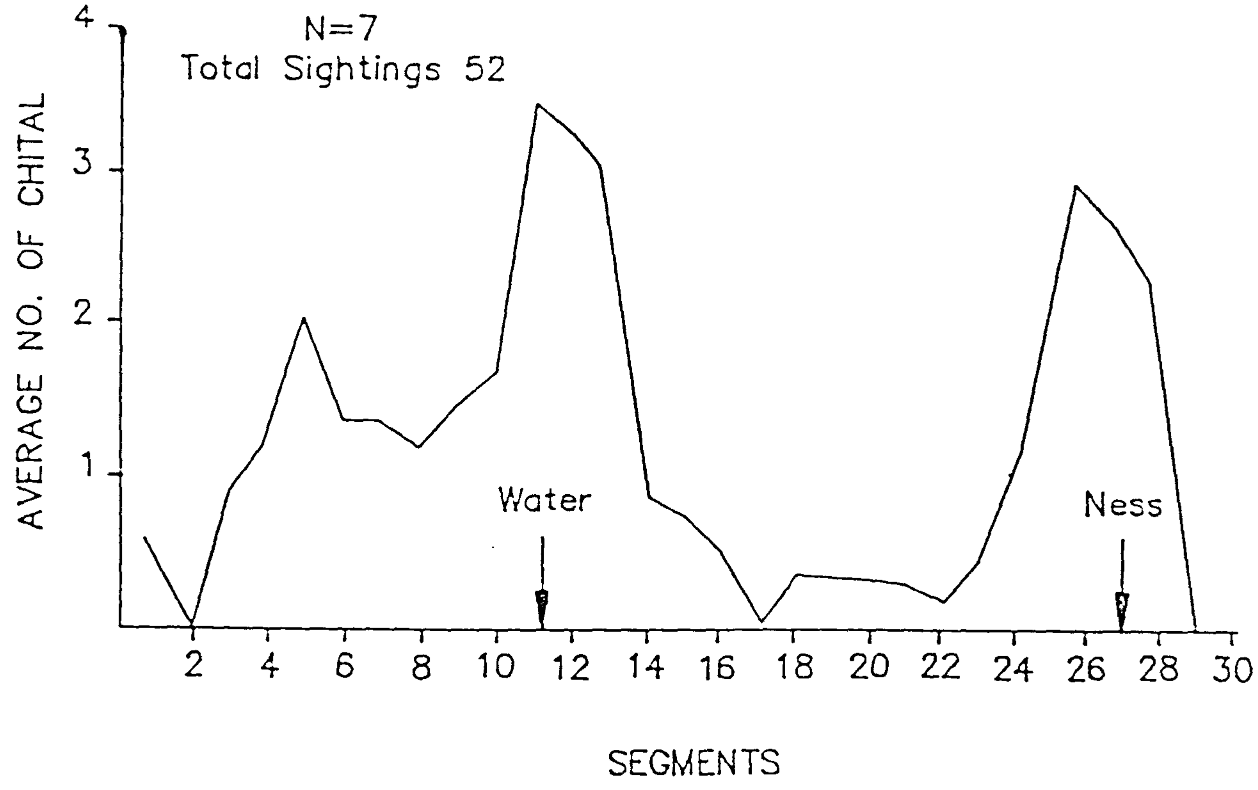


Fig. 27: Average no. of chital/segment on raidi foot transect in Sanctuary West (winter 1988)

CHAPTER - 7

DIETARY ANALYSIS

7.1 INTRODUCTION: Food availability is one of the most important factor influencing the distribution of free ranging animals and hence formulation of management strategy for a protected area necessarily requires adequate information on the food habits of the concerned species (Martin, 1955; Wilkins,1957; Chamrad and Box, 1968;Boeker *et al.*, 1972;Chamrad *et al.*, 1978; Fitzgerald and Waddington, 1979; Cooperrider *et al.*, 1980; Korschgen *et al.*,1980; Kessler *et al.*, 1981; Holecheck *et al.*, 1982; Gill *et al.*, 1983) Equally important for sound management is the information on spatio-temporal variation in food availability, possibility of competition for certain food sources and of food regulating the ungulate population. Detailed dietary studies on different ungulate species are lacking and very few systematic studies have been conducted so far (Schaller,1967; Berwick,1974; Sharatchandra and Gadgil, 1975; Dinerstein, 1980; Green 1985; Chattopadhya and Bhattacharya, 1986; Haque, 1990 ; Shankar and Johnsingh,1991). These studies have provided accounts of food spectrum and seasonal variation in diet of different species. However, as a whole, studies on food habits in Indian subcontinent have lagged behind in comparison to Africa (e.g. Lamprey, 1963; Gwynne and Bell, 1968; Stewart,1971; Stewart and Stewart, 1971; Hofman and Stewart,1972; Rodgers, 1976; Hoppe *et al.*, 1977; Jarman and Sinclair,1979; Breytenbach and Skinner, 1982; Owen-Smith and Cooper, 1983; Hansen *et al.*, 1985; Attwell and Bhika, 1985; McNaughton and Georgiadis, 1986) and north America (e.g. Chamrad and Box ,1968; Drawe, 1968; Chamrad *et al.*, 1978; Krausman,1978; John *et al.*, 1980) where extensive research on food habits has resulted in significant advancement in the field of wildlife management. Probable factors which hampered such studies in India, include very limited scope for direct observations of animals in most of the forested habitats and lack of realisation in India of the importance of pellet and rumen content analysis. Fortunately for the present study, there was excellent scope for direct observations in the field.

7.2 DATA COLLECTION : Direct observations were taken on feeding ungulates on daily basis while conducting regular vehicle and line transect census. The procedure of data recording were scan and focal animal sampling method (Altman,1974). The animals were observed as long as feeding activities continued and the animals were in sight.

7.3 DATA ANALYSIS: The monthly direct observations were summarised on a seasonal basis to calculate the contribution of different plant species as well as browse to grass ratio. The low sample size did not allow calculation of monthly variation in the dietary differences in different sex and age groups. The biomass clippings and the phenological studies were summarised on monthly basis.

7.4 RESULT:

7.4.1 Biomass measurement: Standing crops of grasses and herbs were measured near kamleshwar Dam area in two different plots located in valley and on hill side during 1987 and sanctuary west and national park in 1988 for two consecutive years. Continued excessive grazing by domestic livestock, failure of monsoon in 1987 had major effects on the ground cover. The standing crops in two plots were 20 kg/ha and 29 kg/ha on the hillside and valley respectively. The growth of opportunistic weeds like *Cassia tora* and *Neurocanthes* was slow as compared to normal monsoon year when growth is rapid due to regular precipitations. The peak growth of grasses and herbs measured during October was 180 kg/ha and 148 kg/ha in both the plots which is low against the previous months figure (236 kg/ha and 244 kg/ha) for hillside and valley. The decline in standing crop resulted due to excessive grazing by large numbers of cattle which moved in Gir during a strike period of the forest department and failure of rain in September. The standing crops in moderately grazed areas during October was 400 kg/ha which could be compared width the measurements taken in pure stands of *Themeda quadrivalvis*, *Sehima nervosum* and *Apluda mutica* where biomass was 1620 kg/ha, 1590 kg/ha and 1590 kg/ha respectively with moderate grazing. The standing crop declined further in both the plots. During December, the standing crop was 70 kg/ha. The condition of grass cover was slightly better in national park where the biomass was 514 kg/ha as compared to Kamleshwar.

Grazing by outside cattle had devastating effects on the grass cover, otherwise the biomass would have been much higher despite the failure of rains in the study area. The condition of grass cover further deteriorated in Gir until the arrival of the next monsoon in 1988. Nearly 200 mm rainfall during the first week of the monsoon helped in the rejuvenation of the grass covers. The opportunistic weeds like *Impatience balsamina* and *Cassia tora* were first to establish themselves. Continued long spells of rains did not allow the growth of grasses and for the first two months these two herbs dominated the ground layer.

The standing crop of grasses and herbs in the month of June was 12 kg/ha in the overgrazed areas of the Kamleshwar Dam. The conditions improved as the rain continued. In Kamleshwar plot there was no obvious differences in the standing crops of areas of moderate and heavy grazing input however there were wide differences in the sanctuary west and national park figure. The standing crop was 2040 and 5404 kg/ha in sanctuary west and national park during October respectively. Once the grasslands matured, the standing crop also declined in both the strata. The *Themeda quadrivalvis* and *Apluda mutica* as compared to 1987.

7.4.2 <u>Phenological observations</u>: The 1987 data for phenology of 25 trees and shrubs are summarised on monthly basis and various phenological stages are shown in Figure 30. The population of one plant species may show variation in various phenological stages due to local geographical, climatological and edaphic differences in different parts of Gir.

The flowering in different plant species was continuous throughout the year, however peak flowering was recorded during monsoon when 30% of all the species were flowering . The fruits of different plant species were available to herbivore species throughout the year but the fruiting peak was recorded in mid November when 36% of all the plant species were fruiting. The trees and shrubs started dropping their leaves from August which was too early due to failure of monsoon. The peak in leaf falling was reached in mid-February. The plants remained leafless for a brief period during mid-February to the late March, after which most of plant species grow their pre-monsoon flush. The plant which started growing their leaves first were *Holarrhena antidysenterica*, *Emblica officinalis* and *Butea monosperma*.

Two phenological stages i.e. fruiting and the growth of new leaves before monsoon rains were important for the ungulates in Gir. The fruits of different plant species were utilised by all three ungulate species. The second consecutive drought year altered the phenological pattern of all shrubs and tree species drastically. Drought had a pronounced effect on the leaf falling and leaf inception. All the plant species studied shed their leaves, earlier from expected time. The plant had leaf inception on a normal schedule but the leaves grew for a short period, died and fell. This pattern continued till the arrival of the monsoon.

Caterpillar infestation on the teak leaves till their maturation is a topic concern in Gir. This is not a new and local phenomenon but has been observed in other teak dominated forest also. The caterpillar feed voraciously on the leaves and inflorescence of the teak and what is left is the skeleton of leaves. Observation suggest that a very high percentage of teak plants get infested every year. Only a small percentage of teak trees bear fruit during the fruiting season.

7.4.3 Dietary pattern:

7.4.3.1 Chital

The chital utilised 38 species of trees and shrubs, ten species of grasses and two species of climbers in Gir (Table 53). Most of the plant species reported were seen taken during direct observation. However a small number of plants were identified from the rumen contents too.

Chital is a mixed feeder as reflected from the composition of diet spectrum. It utilised browse and grass in varying proportion during different seasons. As a whole grass dominated the diet throughout 1987 (Table 46).

During winter 1987, the chital diet consisted of grass and browse in almost equal proportion. The shrubs utilised in greater proportion were *Acacia nilotica*, *Capparis sepiaria*, *Carissa opaca* and *Zizyphus mauritiana* (Table 96).

As the grasses mature by this time with low nutritional status, chital supplement their diet by utilising nutritious fruits of various shrubs. The grasses utilised during this period were *Apluda mutica*, *Themeda quadrivalvis* and *Chionachne kaenigii* in greater proportion as compared to others.The proportion of grasses in chital diet increased considerably during summer 1987 with dominance of *Apluda mutica* and *Themeda quadrivalvis* in the diet. *Acacia nilotica*, *Bauhinia racemosa*, *Carissa opaca*, *Tectona grandis* and *Zizyphus mauritiana* were some of the shrub species dominant in the diet.

The monsoon failed to arrive in Gir during 1987 and low rainfall did not bring any significant change in grass cover. However the grass consumption increased tremendously in chital's diet. Chital congregated in big herds and were seen nibbling on the fresh grass growth. The proportion of grasses dropped in the chital's diet during the post-monsoon season. *Apluda mutica* and *Themeda quadrivalvis* largely dominated the grass component of chital's diet.

During the winter of 1988, the chital utilised browse in far greater proportion than the previous year. The grass cover deteriorated to its lowest level and chital supplemented their diet by available fruits (Table 47). *Acacia nilotica*, *Capparis sepiaria*, *Helicteres isora* and *Zizyphus* species dominated the diet of chital. During summer of 1988, the proportion of grass showed an increase in chital diet however browse contents largely dominated the diet. By the end of the summer season, Gir was highly overgrazed except for few areas in the national park. The high browse intake during 1988 was more due to scarcity of grasses rather than any other factor. With a continuous spell of one month rains in July 1988, which brought dramatic changes in grass cover, the grasses again constituted the bulk of the chital's diet in monsoon and post-monsoon season.

7.4.3.2 Sambar

The sambar is also a mixed feeder taking grasses and browse in varying proportion depending upon the availability of the food resources (Table 48). The sambar utilised 29 species of trees and shrubs and one species of climber (Table 54), a list incomplete due to the low observation hours. Observations suggest that during winter 1988, sambar subsisted almost on browse material. *Capparis sepiaria, Emblica officinalis, Helicteres isora, Xeromphis spinosa, Tectona grandis* and *Wrightia tinctoria* dominated the diet of sambar during this season.

The grass to browse ratio remained consistent during summer season and a greater range of shrubs were utilized during this season (Table 97). *Helicteres isora, Tectona grandis and Wrightia tinctoria* contributed in higher proportion in sambar's diet than other browse species. During monsoon season, the bulk of the sambar's diet consisted of grasses. However a small sample size during monsoon and no sighting of sambar during post-monsoon season.

During winter and summer seasons, bark of a number of plant species dominated the diet of sambar as compared to leaf/shoot component of browse (Table 50). Nearly eight species of plants were recorded for having feeding signs of sambar. The bark utilization in sambar's diet decreased to nil during monsoon 1988 when sambar totally shifted to leaves and shoots. There existed a clear selection for the bark of certain plant species as compared to others. *Wrightia*, *Xeromphis* and *Tectona* bark were utilized more compared to other plant species (Table 51).

7.4.3.3 Nilgai

The nilgai also utilised grass and browse in varying proportions during different seasons. 19 species of trees and shrubs were identified to be utilized by the nilgai in Gir. The nilgai utilized all the available plant parts readily such as pods, leaves and twigs. The diet consisted of browse as well as grasses during the winter season (Table 49). *Acacia leucophloea, Butea monosperma* and *Zizyphus mauritiana* contributed in higher proportion than any other shrub species in the diet of nilgai. *Apluda mutica* and *Themeda quadrivalvis* dominated the grass proportion. Nilgai shifted to total browse material during summer season. *Acacia leucophloea, Butea monosperma* were again the two species significantly constituting the bulk of nilgai's diet.

The *Acacia* and *Zizyphus* species as such were utilized by all the wild ungulates in Gir. However there existed a clear difference in the utilization of these plant species (Table 52). During winter season apart from other plant species, the chital utilized *Acacia nilotica* and *Zizyphus mauritiana* in greater proportion whereas nilgai largely subsisted on *Acacia leucophloea*. A similar pattern existed during summer 1988 in the utilisation of *Acacia* and *Zizyphus* species. This not only avoided competition for the available feeding resources but also allowed efficient utilisation by these herbivore species.

7.5 DISCUSSION

Before starting a discussion on food habitats, grass to browse ratio, factors affecting this ratio and what it may mean for management of the ungulate community in Gir, a review of description of food habits of these species in other areas would be helpful. As already discussed the flight distance, shyness of ungulate populations to the observer, and the local disturbance made long continuous feeding observations extremely difficult. All these factors were responsible for the low sample sizes of feeding observations. The observations represent the entire study area due to the fact that they were taken mostly while conducting vehicle counts and sampling different management units for the feeding observation purposes. Can we expect some difference in dietary pattern as regard to the different habitats, units and land forms, and if so how representative these low sample sizes are? Considering the fact that animals do have clear preferences for particular habitat type and the habitat consists of mosaic of vegetation types having different rainfall inputs, food availability and degradation. It will not be relevant to consider data sufficient to represent the plant species composition of herbivore diets. However as far as the broad grass to browse ratio is concerned it does reflect the condition existing in the field. The result of rumen analysis might provide basis to compare the validity of these low sample sizes.

Schaller (1967) analyzed 12 rumen samples of chital during different months and found the grass contributed more than 90% during all the seasons. The browse contributed in low percentage which was reduced to traces during monsoon period.

Sharatchandra & Gadgil (1975) in Bandipur and Dinerstein (1980) in Karnali Bardia in Nepal also found the grass forming the bulk of chital's diet and browse plants contributing marginally to it. The main factors identified affecting the diet selection were phenological, nutritional status of plants and to some extent the annual burning regimes. In all three areas, grasses grow after the rains in May or June creating an optimum foraging conditions during monsoon and become dormant during mid-winter after the seeding. The animals supplement their diet after this period with browse material till the grazing condition once again improved after the burning of grasses which starts after mid-December. The grasses follow the same pattern of growth in Gir except that late fires in March do not result in fresh grass growth due to lack of moisture. During monsoon and post-monsoon seasons., grasses contributed the bulk of the chital diet. This could be attributed to a very high nutritional status and abundance of the grasses. At this time shrubs also provide green leaves and shoots but due to the fact that chital are primarily grazers, they consume grasses in bulk but as the grasses mature, chital supplement their diet with browse (leaves and fruits) of a number of plant species. There appears to be two factors which seem to be responsible for higher browse consumption. They are, phenology and fawning season of chital in Gir. As evident from phenological chart nearly 36% of shrubs and trees were fruiting during winter season and fruits of some species persisted till late February. The chital utilized *Acacia* species pods and *Zizyphus* species fruits (Rumens collected during this period had fruits in greater proportion than any other food component). The fawning season coincided with higher browse intake. It is probable that lactating females utilized the browse mainly because of higher demand of the nutritious food. The low sample size does not allow evaluation of dietary pattern for different age and sex categories and therefore the hypothesis cannot be tested. The data suggested higher grass consumption during summer at a time when grasses remain low in protein content. There appears to be two factors which contribute to this high intake of grasses:

i) A short scarcity period of browse material during the peak leaf fall.

ii) Peak rutting season coinciding with higher grass consumption. Animal would require more time and energy in locating the scarce and unevenly distributed browse material during summer. It seems that animals subsist on low quality diet and spend more time and energy on rutting activities rather than any other behavioural trait.

Do the chital have a generalized feeding pattern which is repeated almost every year? The answer may be yes if we look at the dietary pattern next year in the light of condition which existed during 1988.The browse content was high during winter and summer season of 1988, a far higher proportion than the previous year due to the scarcity of grasses because of excessive grazing and second consecutive drought. If the rainfall pattern would have been normal, the browse consumption would have followed the same pattern. However this requires further investigation because it is this information which can help managers in making sound decisions (eg. Do we require to provide supplement food? Or the animals can manage without least interference from managers).

Sambar is browser as the available literature suggests and the grasses comprise only a fraction of their diet. The sambar switched to bark of several plant species as the winter progressed and it remained a major food source until the arrival of monsoon. There was no bark utilization until the next summer. The obvious questions which arise here are :

i) Is the utilisation of bark an essential component of sambar diet?

ii) If no, then what were the factors which led to such heavy debarking in Gir.

There have been past records of sambar feeding on bark of different plant species (e.g.Schaller, 1967). However no such incident was observed prior to the 1987 drought in Gir (Berwick, 1974 reported no such phenomenon). This could be due to several reasons:

i) Ungulate species maintain a resource of partitioning mechanism among themselves to avoid competition for a common food component and facilitate their coexistence during scarcity period.

ii) Any mineral present in the bark which is crucial for the animal during a particular period.

The chital population switched to more and more browse as the winter progressed in the drought year. Sambar probably utilised bark to avoid the competition for food resource with chital and nilgai. The selection and avoidance patterns for a bark of particular plant species may be a result of several factors such as:

(a) Palatability of the bark material.

(b) Fibre content of the bark material.

(c) Any mineral which may be required by the animal.

(d) Distribution and availability of the plant species.

(e) Habitat utilization pattern of animal species.

The nilgai exhibited a mixed feeding pattern and browse dominated its diet throughout the season. The nilgai can subsist on low quality of food and can survive in harsh environments or sub optimal habitats due to its large body size and reduced energy requirements per unit surface area.

The large ungulate community of chital, sambar and nilgai avoided competetion for the same feeding resources and several resource partitioning mechanism were obvious from the data in Gir. The large ungulate community of chital, sambar and nilgai avoided competition for the same feeding resource by

i) their overall distribution throughout the sanctuary (eg. chital attaining its maximum density in western Gir, sambar in national park and the nilgai being distributed in Eastern Gir).

ii) Selecting different habitat types at one time (Chital preferring TAZW and THW with Flat areas, whereas sambar preferring hilly and rugged terrain with dense shrub cover in TBSW and MTW and nilgai utilized vegetation communities of Eastern Gir).

iii) Utilizing a subset of available plant species and plant parts (Table 46).

iv) exploiting the food at different heights in the available habitat types.

Table 46. Chital dietary analysis (grass to browse ratio) 1987 based on direct sighting records.

Season	N	Grass	Browse
Winter '87	60	55%	45%
Summer '87	48	70%	30%
Monsoon '87	49	92%	8%
Post-monsoon '87	37	67%	33%

Table 47. Chital dietary analysis (grass to browse ratio) 1988 based on direct sighting records.

Season	N	Grass	Browse
Winter '88	202	11.3%	88.6%
Summer '88	163	30.06%	69.9%
Monsoon '88	128	61.7%	38.2%
Post-monsoon '88	43	97.6%	2.3%

Table 48. Sambar dietary analysis (grass to browse ratio) 1988 based on direct sighting records.

Season	N	Grass	Browse
Winter '88	107	0%	100.0%
Summer '88	127	4.7%	95.3%
Monsoon '88	13	7.6%	92.3%
Post-monsoon '88	-	-	-

Table 49. Nilgai dietary analysis (grass to browse ratio) 1988 based on direct sighting records.

Season	N	Grass	Browse
Winter '88	63	6.3%	93.7%
Summer '88	59	0%	100.0%
Monsoon '88	52	44.2%	55.8%
Post-monsoon '88	-	-	-

Table 50. Sambar dietary analysis (Food components).

Season	n	Bark	Leaves + Shoot	Grass
Winter '88	107	68.2	31.7	0
Summer '88	127	43.3	51.9	47
Monsoon '88	13	--	7.6	923

Table 51. Sambar dietary analysis (Plant species bark utilization).

Winter 87-88 n = 73		Summer 1988 n=55	
Plant species	% frequency	Plant species	% frequency
Bombax ceiba	1.3	Carissa	3.6
Mitragyna	1.3	Mitragyna	9.09
Rendia	26.02	Rendia	21.8
Wrightia	46.5	Wrightia	40.0
Teak	24.6	Teak	25.4

Table 52. Comparison of Acacia-Zizyphus species utilization in three herbivore species.

Winter 1988

Plant species	Chital % frequency	Sambar % frequency	Nilgai % frequency
Acacia nilotica	20.7	--	4.7
Acacia catechu	--	0.93	1.5
Acacia leucophoea	2.9	0.93	34.9
Zizyphus mauritiana	16.3	--	9.5
Zizyphus oenoplea	4.4	0.93	3.1
Zizyphus numularia	5.9	--	--
Zizyphus xylopyros	2.4	--	4.7
Other species	47.4	97.2	41.6

Summer 1988

Plant species	Chital % frequency	Sambar % frequency	Nilgai % frequency
Acacia nilotica	34.3	4.7	10.1
Acacia catechu	--	--	10.1
Acacia leucophloea	--	--	27.1
Zizyphus mauritiana	6.7	3.9	10.1
Zizyphus oenoplea	1.2	--	--
Zizyphus numularia	--	--	--
Zizyphus xylopyros	--	--	--
Other species	57.8	91.4	42.6

Table 53. Dietary spectrum of Chital (Axis axis) in Gir.

Plant species eaten	Part eaten	Degree of use
TREES AND SHRUBS		
Acacia catechu	L+F	X X
Acacia leucophloea	L+S+P	X X X
Acacia nilotica	L+P+S	X X X
Acacia senegal	F	X
Aegle marmelos	L	X
Agave ingens	L	X
Albizia procera	L	X
Balanites aegyptica	L+F	X X X
Barlaria prionitis	L	X X X
Bauhinia racemosa	L+F	X X X
Butea monosperma	L+S	X
Caparis separia	L	X X X
Carissa opaca	L+S+F	X X X
Cassia fistula	F	X X
Cassia tora	P	X X
Dichrostachys cineria	L	X X X
Diospyros melonoxylon	L+F	X X X
Ehretia laevis	L	X X
Embilica officinalis	L+F	X X X
Ficus religiosa	L	X
Flaucortia indica	L	X X
Helicteres isora	L	X X X

Holoptelia integrifolia	L	X X
Holarrhena antidysentrica	L	X X
Ixora arborea	L	X
Morinda tinctoria	L	X
Sapindus emerginatus	L	X
Securinega leucopyros	L	X X
Sygyzium rubicundum	L+F	X X
Tectona grandis	L	X
Terminalia bellerica	F	X X
Terminalia crenulata	L	X
Wrightia tinctoria	L+F	X X
Xeromphis spinosa	L+F	X X X
Zizyphus mauritiana	L+F	X X X
Zizyphus numularia	L+F	X X X
Zizyphus oenoplea	L+F	X X X
Zizyphus xylopyros	L+F	X X X
GRASSES		
Apluda mutica	L+C	X X X
Aristida funiculata	L+C	X
A. ischaemum	L+C	X X X
Brachiaria ramosa	L+C	X X X
Chloris barbata	L+C	X X
Chloris virgata	L+C	X X X
Chionachne kaenigii	L+C	X X X
Digitaria ciliaris	L+C	X X X

Heteropogon contortus	L+C	X X X
Themeda quadrivalvis	L+C	X X X
CLIMBERS		
Asparagus racemosus	L+S	X X X
Comberatum roxbergii	L+S	X X X

L = Leaf, S = Shoot, F = Fruit, P = Pods, C = Culm, X = Selected ones, X X = Selected occasionally, X X X = Selected frequently

Table 54. Dietary spectrum of Sambar (Cervus unicolor) in Gir.

Plant species eaten	Part eaten	Degree of use
TREES AND SHRUBS		
Acacia catechu	F	X
Acacia nilotica	L+F	X X X
Acacia leucophloea	L+S+F	X X X
Adina cardifolia	B	X X X
Bombax ceiba	B	X X X
Bauhinia racemosa	L+F	X X X
Capparis sepiaria	L+S	X X X
Carissa opaca	L+B	X X X
Cassia tora	L+P	X
Cassia fistula	B	X X
Dichrostachys cineria	L	X X X
Diospyros melonoxylon	L	X X
Emblica officinalis	L+F+B	X X X
Ficus bengalensis	L	X
Ficus religiosa	L	X
Helicteres isora	L+S	X X X
Morinda tinctoria	L	X
Mitragyna parvifolia	B	X X X
Neuroeanthes	L	X
Sygyzium rubicundum	L	X
Tectona grandis	B	X X X

Terminalia bellerica	F	X X
Terminalia crenulata	B	X X
Wrightia tinctoria	B	X X X
Xeromphis spinosa	L+B	X X X
Xeromphis uligionosa	B	X X X
Zizyphus mauritiana	L+L	X X X
Zizyphus oenoplea	L	X X X
Zizyphus xylopyros	L	X X X
CLIMBERS		
Comberatum roxbergii	L+S	X X X

L = Leaf, S = Shoot, F = Fruit, P = Pods, B = Bark, X = Selected ones
X X = Selected occasionally, X X X = Selected frequently

Table 55. Dietary spectrum of Nilgai (Boselaphus tragocamelus) in Gir.

Plant species eaten	Part eaten	Degree of use
Acacia catechu	L	X X X
Acacia nilotica	L+S+P	X X X
Acacia leucophloea	L+S+P	X X X
Balanites aegyptica	L+S	X X X
Bauhinia racemosa	L+S	X X X
Butea monosperma	L+S	X X X
Capparis sepiaria	L	X X
Carissa opaca	L+S	X X
Diospyros melonoxylon	L	X
Dichrostachys cineria	L	X X X
Emblica officinalis	L+S	X X
Helicteres isora	L+S	X X X
Morinda tinctoria	L	X
Terminalia crenulata	L	X X
Wrightia tinctoria	L+P	X X X
Xeromphis spinosa	L+L	X X
Zizyphus mauritiana	L+F	X X X
Zizyphus oenoplea	L+F	X X X
Zizyphus xylopyros	L+F	X X X

L = Leaf, S = Shoot, F = Fruit, P = Pods, X = Selected ones
X X = Selected occasionally, X X X = Selected frequently

Table 56 Debarking in different districts of Gir (Trees and shrubs > 2m height).

District	Trees sampled	Trees debarked	% Debarking
Sanctuary West	1809	239	13.2
National Park	1828	142	7.7
Sanctuary East	514	0	0.0

Table 57. Proportion availaible (P_{io}), Proportion debarked (P_{ie}) and 95% Bonferroni confidence limits for different plant species in Sanctuary west and National Park.

(n = Number of individuals sampled, D = Number of individuals debarked, - = Avoided, + = Preferred, 0 = Debarking proportional to availability)

Plant species	n	P_{io}	D	P_{ie}	Confidence limits for P_{ie}			Preference rating
SANCTUARY WEST								
Cassia fistula	7	0.0083	1	0.0041	0.007514	$\leq P_1 \leq$	0.015714	0
Ehretia laevis	8	0.0095	1	0.0041	0.007514	$\leq P_2 \leq$	0.015714	0
Emblica officinalis	28	0.0332	10	0.0418	0.005423	$\leq P_3 \leq$	0.078176	0
Flaucortia indica	5	0.0059	1	0.0041	0.007514	$\leq P_4 \leq$	0.015714	+
Sapindus emarginatus	3	0.0035	1	0.0041	0.007514	$\leq P_5 \leq$	0.015714	+
Schrebera swietenioides	9	0.0107	1	0.0041	0.007514	$\leq P_6 \leq$	0.015714	0
Tectona grandis	538	0.6397	34	0.1422	0.078718	$\leq P_7 \leq$	0.363118	-
Wrightia tinctoria	150	0.1783	121	0.5062	0.415325	$\leq P_8 \leq$	0.597074	+
Xeromphis spinosa	89	0.1058	67	0.2803	0.198661	$\leq P_9 \leq$	0.361938	+
Xeromphis uliginosa	4	0.0047	2	0.0083	0.008190	$\leq P_{10} \leq$	0.024790	+

NATIONAL PARK

Boswellia serrata	44	0.0595	1	0.0070	0.011820	$\leq P_1 \leq$	0.025820	-
Grewia tiliaefolia	28	0.0378	1	0.0070	0.011820	$\leq P_2 \leq$	0.025820	-
Millusa tomentosa	19	0.0257	1	0.0070	0.011820	$\leq P_3 \leq$	0.025820	0
Tectona grandis	478	0.6468	8	0.0563	0.004266	$\leq P_4 \leq$	0.108333	-
Wrightia tinctoria	139	0.1880	110	0.7746	0.680275	$\leq P_5 \leq$	0.868924	+
Xeromphis spinosa	27	0.0365	18	0.1267	0.051610	$\leq P_6 \leq$	0.201789	+
Xeromphis uligionosa	4	0.0054	3	0.0211	0.011342	$\leq P_7 \leq$	0.053542	+

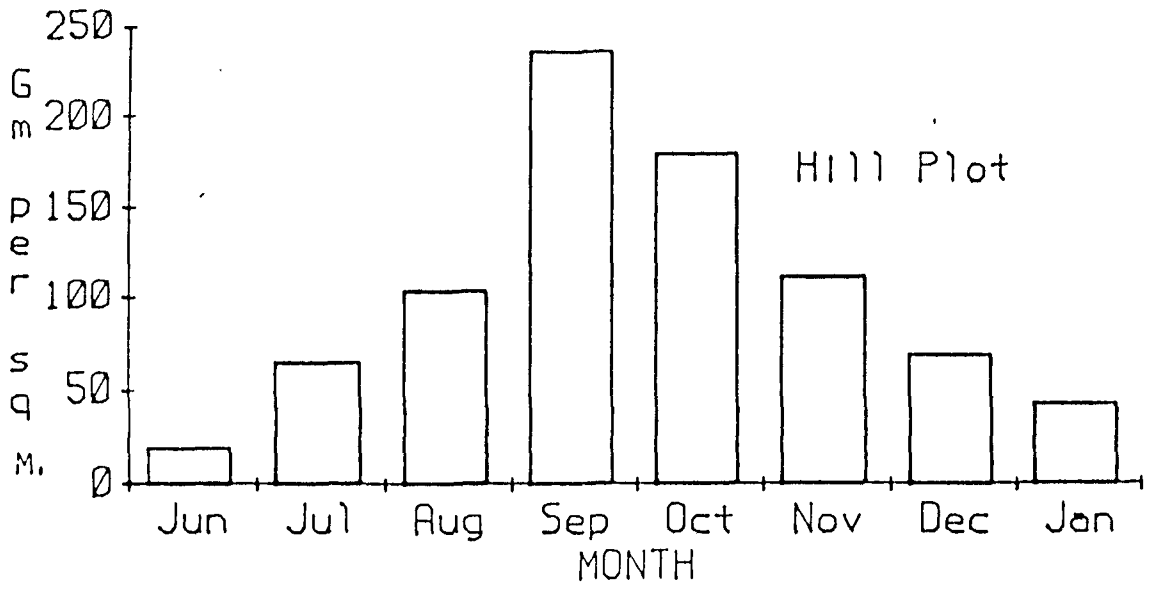
Table 58 Proportion available (P_{io}), proportion debarked (P_{ie})and 95% Bonferroni confidence limits for different girth classes, in Sanctuary West and National Park.
(n = Number of individuals sampled . D = Number of individuals debarked, - = Avoided, + = Preferred, 0 = Debarked proportional to availability).

Girth classes (cm)	n	P_{io}	D	P_{ie}	Confidence limits for P_{ie}			Preference rating
SANCTUARY WEST								
0-20	228	0.2645	111	0.4644	0.379555	$\leq P_1 \leq$	0.549244	+
21-40	280	0.3248	84	0.3514	0.270183	$\leq P_2 \leq$	0.432616	0
41-60	231	0.2679	23	0.0962	0.046037	$\leq P_3 \leq$	0.146362	-
61-80	87	0.1009	13	0.0543	0.015749	$\leq P_4 \leq$	0.092850	-
81-100	30	0.0348	7	0.0292	0.000557	$\leq P_5 \leq$	0.057842	0
101-120	6	0.0069	1	0.0041	0.006770	$\leq P_6 \leq$	0.014970	0
NATIONAL PARK								
0-20	200	0.2372	67	0.4718	0.361623	$\leq P_1 \leq$	0.581976	+
21-40	213	0.2526	57	0.4014	0.293214	$\leq P_2 \leq$	0.509585	+
41-60	256	0.3036	13	0.0915	0.027866	$\leq P_3 \leq$	0.155133	-
61-80	129	0.1530	5	0.0352	0.005472	$\leq P_4 \leq$	0.075872	-
81-100	31	0.0367	0	0.0				
101-120	14	0.0166	0	0.0				

Table 59 Percentage of trees in different damage categories in Gir.

(n = Number of individuals sampled, D = Number of individuals debarked).

Plant species	n	D	Low D	Low %	Medium D	Medium %	Severe D	Severe %	% Overall Damage
Boswellia serrata	53	1	1.8	0	0	0	0	0	1.8
Cassia fistula	26	1	1	3.8	0	0	0	0	3.8
Ehretia laevis	8	1	0	0.0	1	12.5	0	0	12.5
Emblica officinalis	68	10	5	7.3	3	4.4	2	2.9	14.7
Flaucortia indica	7	1	1	14.2	0	0	0	0	14.2
Grewia tiliaefolia	50	1	0	0	1	2.0	0	0	2.0
Millusa tomentosa	24	1	1	4.1	0	0	0	0	4.1
Sapindus emarginatus	3	1	0	0	1	33.0	0	0	33.3
Schrebera swietenioides	10	1	1	10.0	0	0	0	0	10.0
Tectona grandis	1016	42	20	1.9	17	1.6	5	0.49	4.1
Wrightia tinctoria	289	231	21	7.2	94	32.5	116	40.1	79.9
Xeromphis spinosa	116	85	18	15.5	29	25.0	38	32.7	73.2
Xeromphis uliginosa	8	5	0	0.0	1	12.5	40	50.0	62.5
Total	1678	381	69	4.1	147	8.7	165	9.8	22.7



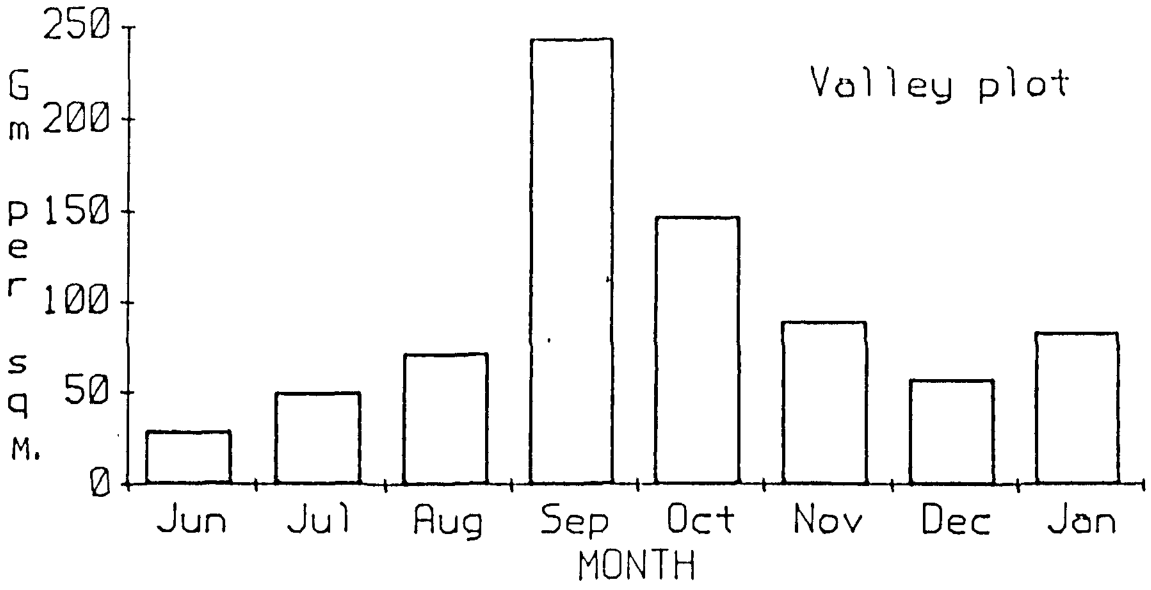
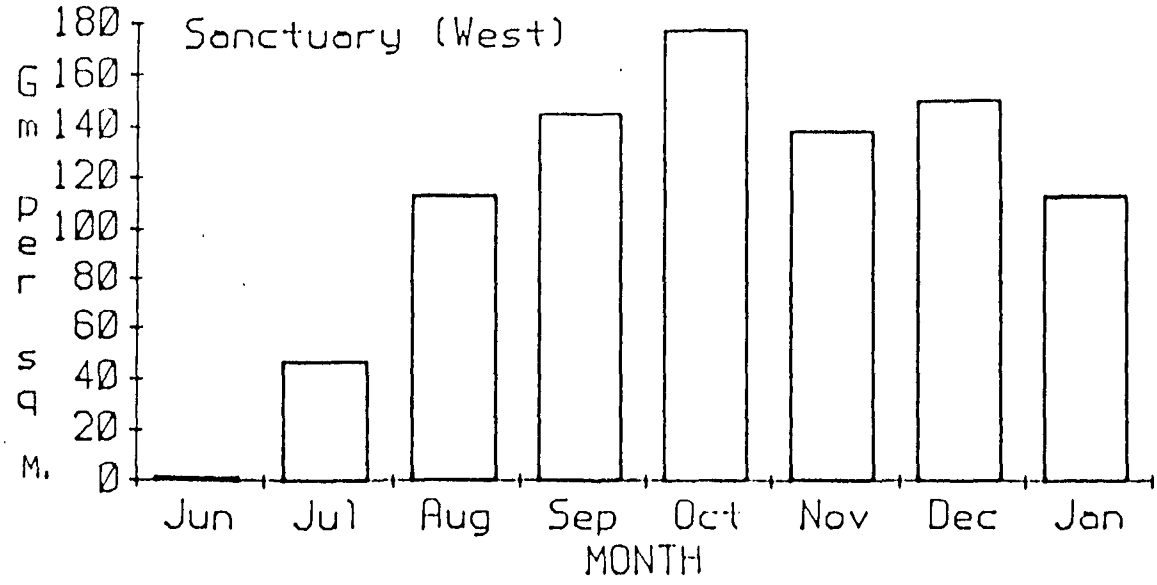


Fig. 28: Standing crop of grasses and herbs in Kamleshwar area from June '87 to Jan. '88.



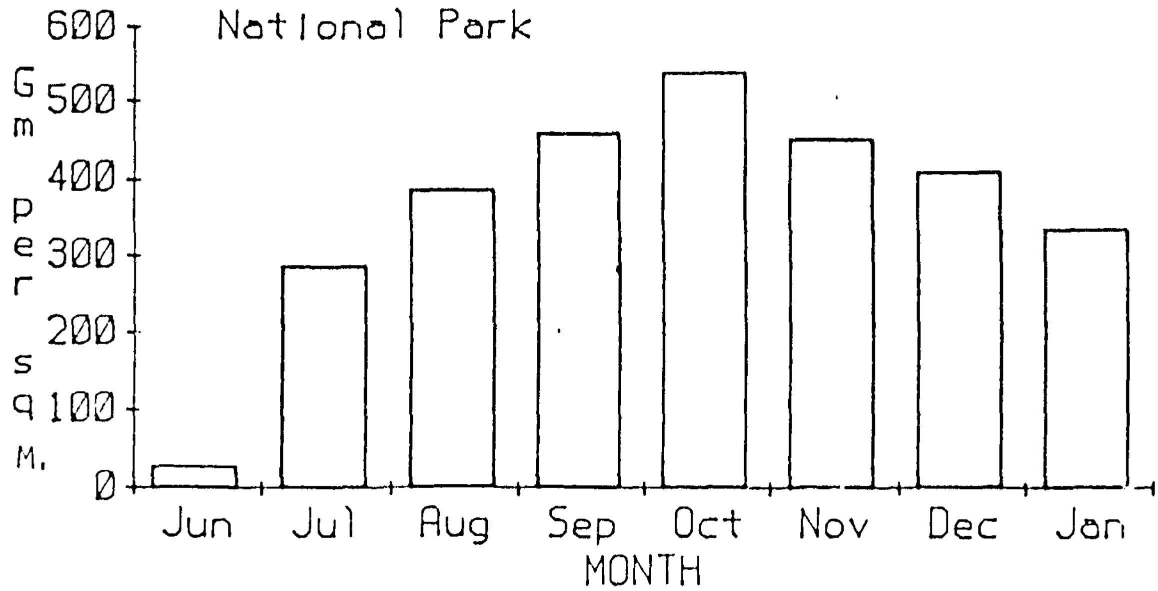
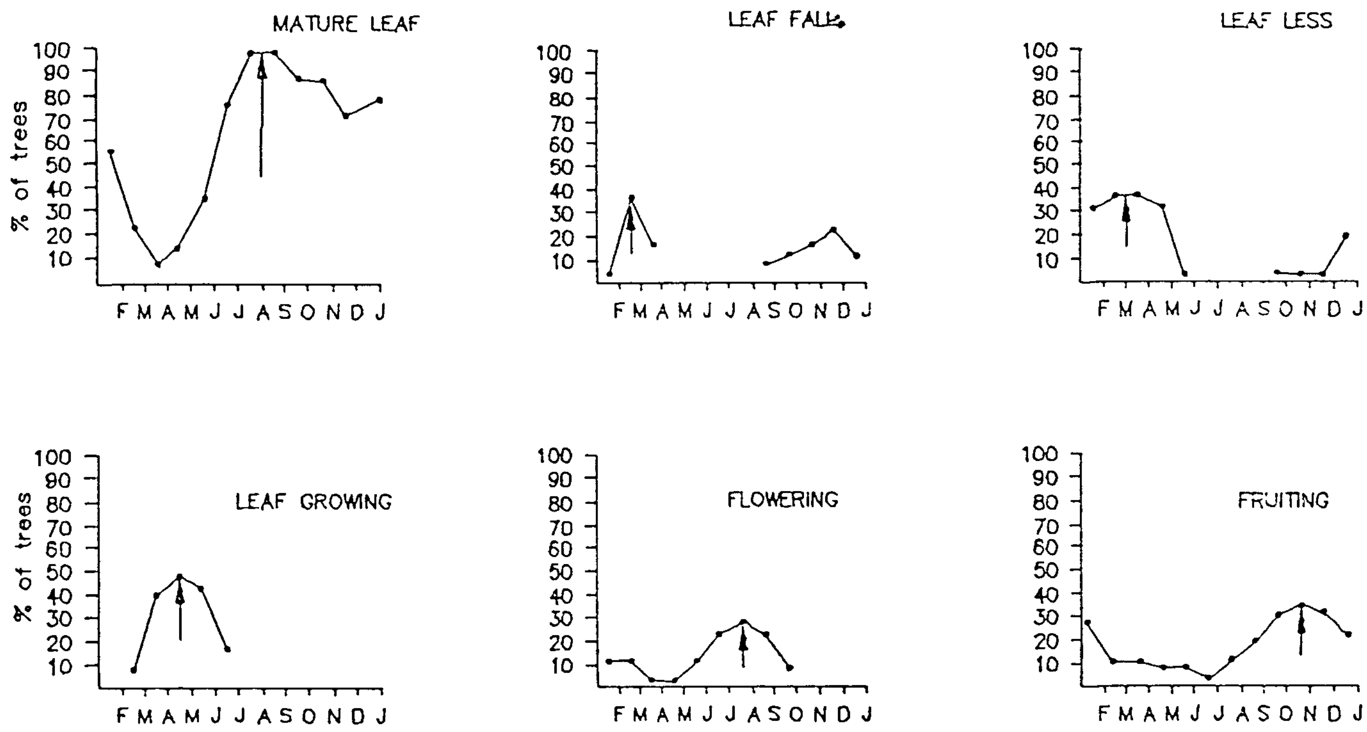


Fig. 29: Standing crop of grasses and herbs in Gir from June '88 to Jan '89.

Fig. 30 Phenology of 25 food plants (trees and shrub species)
in Gir Lion Sanctuary, 1987



CHAPTER- 8

MANAGEMENT IMPLICATIONS

8.1 INTRODUCTION: Gir Lion Sanctuary and National Park, with an area of 1412 km^2 have the distinction of being the largest tract of natural vegetation in the Saurashtra region of Gujarat and the last refuge the Asiatic lion (*Panthera leo persica*). The Gir wildlife sanctuary was established during 1965 with an objective to protect its nature fauna and flora. The sanctuary was expanded to its present size in 1974. The sanctuary and national park area (hereafter referred as Gir) is now, however, being protected and managed to conserve the sole wild population of Asiatic lion. A programme of biological research during 1960's and 70's described the level of impacts of local Maldhari grazier on the Gir ecosystem (Hodd, 1969; Joslin, 1973; Berwick, 1974). These impacts (among other things) led to the cattle becoming the major prey item in lion's diet. Iion's diet comprised of 75% of livestock and 25% of wild ungulates. The Gir ecosystem showed signs of degradation as the area remained overgrazed for most of the year and domestic livestock populations remained for above the level of its carrying capacity. Realizing the gravity of the situation, the park managers then took several major conservation measures to reduce these impacts. These measures included shifting of a number of pastoral settlements (locally known as nesses), outside Gir, creation of a 258 km^2 of national park within the sanctuary limits, water hole development, exclusion of migratory cattle and better protection. Unfortunately after this, there was no follow up programme to evaluate the impacts of these conservation measures in Gir. The Wildlife Institute of India in collaboration with Gujarat Forest Department started Ungulate-Habitat Ecology project in 1987 to evaluate the past management inputs and to study the existing condition of the Gir habitat. The project aimed at gathering crucial information about the Gir ecosystem and to incorporate the findings into better management of Gir.

This chapter deals with the management implications of research findings of this study. Gir having the sole populations of lions, has attracted quite lot of attention from national and international conservation agencies and perception about problems of lions as well as Gir as a whole differ widely. In such a scenario, as it happens in most cases, many issues related to Gir are controversial. Controversies at various levels, should ideally have resulted in better coordination among various agencies, but it has been totally otherwise in case of Gir. The ideas presented here in this chapter reflects the opinion of the author and it is not necessary that people agree or will agree with these ideas.

8.2 PAST MANAGEMENT POLICIES : Prior to independence, Gir forest was part of former Junagarh estate. The former rulers of Junagarh estate protected and managed Gir forest for revenue by exploitation of teak forest and allowing grazing of livestock of Maldharis and from the surrounding villages. The forest land thus cleared, was colonised by people and brought under cultivation. The former rulers of Junagarh after realizing the endangered status of lions at the turn of this century banned the hunting of lions and during 1920, a small portion of Gir forest (Devalia block) was declared as a sanctuary. However the exploitation of Gir forest continued in the form of extraction of teak on 40 years rotation basis. The forestry operations were carried out according to the guidelines spelled out in forest working plans. The Gir forest was declared as sanctuary in 1965 and later expanded in 1974. There was however no change in management policy except that lions were accorded better protection. The forestry operations continued as it is in Gir. It was during 1972, after the culmination of Gir Research Project, that Gujarat Govt., in collaboration with WWF-International launched Gir project. Under this project, Gujarat Forest

Department undertook a Maldharis translocation program to reduce the biotic interference as well as the level of livestock grazing. Under this scheme 63 Maldharis nesses (Pastoral settlements) with their cattle populations were shifted outside the boundaries of Gir. The other major management actions included creation of national park within sanctuary, water hole development, fire protection, exclusion of migratory livestock from Gir, complete end to the forestry operations and effective protection against poaching. Since its establishment, the sanctuary is being managed through a conservator of forest and 3 DCF. While the two territorial DCF handle the protection and overall management of Gir, the DCF posted at Sasan looks after the management of tourism and wildlife. At present, Gir lacks a management plan and as such there are no set guidelines for management of entire protected area. The last working plan implemented in 1976 has actually lapsed in 1986 (Chellam 1993).

8.3 VEGETATION : The vegetation of Gir, though described in terms of floristics and tree species association previously had lacked a simple hierarchical habitat classification which could be utilized for overall management of vegetation and ungulate populations. The classification of major habitat types on the basis of their species composition and topography would be easily recognised by managers and researchers. It is thus expected that such a broad classification would be the basis of future research and management actions. It is to be emphasized that minor spatial variation in species composition within each habitat type needs to be overlooked as classification of vegetation at that finer scale would only result in confusion and would be of use no future.

The data on tree an shrub density in different management units showed significant differences in cover and density values. This change is quite obvious inside national park specially in shrub class 1-2 m and 2-6 m. This has been a direct consequence of protection offered to entire national park from livestock grazing and fire. The policy of total protection inside national park and its overall implications needs to be evaluated in context of increase in cover and density, much lower ungulate biomass, uneven utilization of forage and plant species regeneration. The increase in cover inside national park, though suits the overall habitat requirements of sambar,has been largely detrimental for chital and nilgai which prefer slightly open areas with ecotones. The sambar population in Gir is too small (1038 ± 403) in comparison to chital (35290 ± 4436) and has not shown any significant,increase from 1970's. It is possible that high predation pressure by lions is limiting the growth of the sambar population and population is not likely to increase no matter how extensive its habitat may be inside national park. On the contrary, the chital population if carefully managed still has potential to increase substantially and perhaps might be helpful in reducing the predation pressure on sambar population. Therefore efforts should be made to increase the chital densities inside national park. This will not only require management action to halt increase in cover but also some amount of habitat manipulation. Creation of open grasslands with ample ecotones in valleys and flat areas of national park by way of patch cutting, promoting the growth of palatable *Acacia* and *Zizyphus* species and provision of ample water in such areas will certainly have positive impact on chital population inside national park. This exercise may first be carried out on an experimental basis which if done on smaller scale will have no negative impact on sambar population. Moreover the sambar population should by and large remain unaffected with such habitat manipulations as it utilizes hilly steep terrain and comes down to valleys for water only. A look at the species composition data on shrub class 0 - 1 m and 1 - 2 m inside national park reveals dominance of shrubs like *Helicteres isora* and *Holarrhena antidysenterica* as compared to sanctuary west where these categories have higher species richness of palatable species. Such a situation is highly undesirable and can never be conducive for ungulate biomass. How this trend can be reversed is again a question which can only be answered through manipulation. Managers will have to be open to such manipulation if there is a genuine need for it and if it is in the interest of maintenance of high ungulate biomass. The entire national park area can be divided into smaller grids and areas having pure stands of these species or their dominance in shrub larger can be mapped on it. Selective clearing of *Helicteres isora* and *Holarrhena antidysenterica* in these areas coupled with controlled burning once in five years would be an ideal management strategy to adopt in this context. This again can be done first on a smaller scale on experimental basis and if such a strategy yields desirable results, may be later adopted for extensive areas inside national park.

The grass production in Gir is as such quite high and as long as there is no failure of monsoon, there is never a shortage of grass inside Gir. It is only the drought years, as it happened in 1987, which results in acute shortage of grass. During the normal monsoon years, substantial amount of grass biomass remains under utilized even after the grass harvest by forest department especially inside the national park area. This is a colossal waste of a resource which very often becomes the basis of conflict between the aspirations of local people and the conservation goals of Gir. Secondly it certainly results in enormous grazing pressure in sanctuary west and sanctuary east from the livestock populations of Maldharis and from surrounding villages. As a result of this grazing, grass cover is eroded and opportunistic weeds such as *Cassia tora* and *Achyranthes aspera* dominate the overall species composition of ground cover in sanctuary west and east. The grazing policy if at all it exists in Gir needs to be reviewed and clearly spelled out keeping in view all aspects of it. I would prefer an even utilization of grass biomass inside Gir which will not only result in optimization of this resource but also halt the degradation of grass cover in certain areas of Gir.

The severe drought in 1987 resulted in very heavy mortality in several tree and shrub species and mortality of this magnitude is likely to have impact on overall species composition of different habitat types in Gir. Certain trees eg. *Acacia senegal* and shrub species (e.g. *Xeromphis spinosa*) are likely to loose their dominance from the vegetation communities and replaced by other species. Moreover removal of the dead individuals of these species will result in opening of the canopy and overall reduction in tree and shrub cover. The impact of such changes in habitat structure on ungulate populations could not have been evaluated immediately after the mortality and monitoring of ungulate populations now can give some idea as to how ungulate populations have responded to it. Unfortunately after the culmination of this study, monitoring of ungulate populations has also been stopped. This is similar to the no information gap between the Gir Research Project and present study and is highly undesirable. Gir with its multitude of problems can not afford such gaps in research. It is urged that managers give top priority to monitoring of ungulate populations to find out the impact of mortality in plant populations on distributions of ungulates. It is clear that highly productive and palatable shrub layer in all management units of Gir contributes a lot to the maintenance of high ungulate biomass and as a consequence of mortality, if this diversity is affected by way of establishment of weeds such as *Lantana camara*, due to opening of canopy, then ungulate populations are likely to suffer in future. *Lantana camara* can be seen establishing it self in riverine and other habitats due to disturbance and it needs to be checked before it grows out of proportion. The increase in cover and density in Gir vegetation is considered detrimental to lion population as it is believed that the increase in cover would influence hunting success of Asiatic lions negatively and thinning of teak forest has been suggested as one of the solution to this problem. This is a totally baseless controversy and if implemented in Gir would play havoc with vegetation as well as ungulate populations. Nobody knows the implications of such large scale thinning in Gir. A cyclone way back in 1982 which uprooted nearly 2.8 million trees and later a severe drought 1987 which caused extensive mortality, have done enough thinning in Gir. Infact Chellam (1993) has found no relation between predation and tree density. Moreover lions take maximum advantage of cover in hunting in Gir.

8.4 UNGULATE POPULATIONS: The estimation of ungulate population size, densities, spatial pattern and overall distribution pattern of different ungulate species inside Gir by vehicle census has yielded vital information on these aspects to managers. First of all it highlights the magnitude of underestimation of ungulate biomass by water hole counts. At present Gir supports, according to the last vehicle census conducted in Gir during summer 1989, 35290 ± 4436 chital, 1038 ± 403 sambar, 605 ± 312 nilgai and 630 ± 288 chinkara. The chital number, for instance, is more than three times higher than the estimates by water hole counts (Table 86).

This suggests that Gir has got sufficient ungulate biomass and is enough to sustain lion populations especially in absence of livestock population from Gir in case a total shifting program of Maldharis and their livestock populations takes place.

The other controversy which needs a total contradiction here is the assumed link between lack of enough prey inside Gir and problems of lions straying out of Gir. The problem of lions going out of Gir has, in recent times, grown out of proportion. Lions have in a short span of time (1988-90) have claimed several human lives and injured scores of people. However, it is totally baseless that this problem is due to lack of enough prey base inside Gir. Due to super abundance of prey (both wild and domestic), lion population is growing steadily in past and being highly territorial, there is an upper limit in terms of number of lions, which Gir can support. The lions which are frequently going out of Gir holds no territories and are mostly surviving in marginal habitats in terms of ungulate biomass. There has been a practice of capturing straying lions and releasing them back in central part of Gir and very often such intruders have again been forced out of Gir. Saberwal *et al.* (1990) have investigated in detail this problem and have proposed several suggestions to solve this problem in Gir.

Estimation of size of ungulate populations is a tricky business and can be a very time consuming job. However considering the amount of information it generates, crucial for management, certain amount accuracy and precision is highly desirable. It is in this context that census policy in Gir needs a total revision especially for ungulates species. Managers in Gir have so far been using water hole count at interval of five years for censusing the ungulates. The water hole count is based on number of assumptions for which data are hard to collect and not available. Moreover it is highly time consuming, has got bias (of unknown magnitude) and involves big manpower and is expensive . Unfortunately census methodologies have not been developed and tested in India as compared to other parts of the world and it is highly desirable that managers should now benefit with the recent advancements in line transect census method. My studies in Gir show that vehicle count method is reliable, efficient and produces unbiased results with less expenditure of money and manpower. The census exercises carried out under this study can serve as model to managers and should be done regularly. The five year gap is highly undesirable for ungulate populations as Gir has a highly unpredictable environment and it is expected that census policy might be reviewed to accommodate an annual ungulate census exercise. The tremendous increase in chital population inside Gir during the last two decades can be considered a rich reward to managers for what has been done by them during this period. I have elaborated to a great extent on the factors which are responsible for this increase in chital population. Apart from other things, I feel the chital population was regulated by the number of livestock inside Gir in sixties and reduction in livestock number by shifting a number of Maldharis nesses had a positive impact on chital population through increased forage production. The domestic livestock still contribute 64% to the overall ungulate biomass in sanctuary west and east respectively. It is highly desirable that this contribution should be brought down to approximately 50% in both management units and its impact on wild herbivore populations evaluated. It is anticipated that chital population will respond positively to such as reduction especially inside sanctuary east where grazing is too severe to allow any increase in chital population.

The ungulate densities are highly variable in space inside Gir and the overall distribution maps of different species should be of great help for managers to concentrate their efforts in those areas where ungulates densities are quite low. The areas where densities are high should serve as model as to what is lacking in areas where densities are low. There is tremendous scape for increasing wild herbivore biomass especially inside national park areas.

8.5 LION POPULATION: The lion population currently estimated to be 284 according to the census carried out by G.F.D. in 1990, is believed to have undergone through a severe genetic bottleneck towards the end of 19th and early 20th century. The total lion population was believed to be less than 20 individuals during the 1900 and 1913 (wynter-Blyth and DharmaKumarsinhji, 1950). After that however, lion population has shown an upward trend and remained well above 200, except during 1968 when the lion population was estimated to be 177 (Dalvi,1969). There are therefore strong possibilities that lion population might be having some inbreeding despite the fact that increase in population size immediately after the genetic bottleneck would have helped the lion population to retain much of its genetic variability. However, being the only population, it is desirable that the present population in Gir should be checked for the manifestations of inbreeding syndrome. Moreover Chellam (1993) has already strongly recommended establishment of a second population in wild. The predation pattern of lions has changed considerably from what was described in 60's by Joslin (1973) and at present the ratio between wild to domestic ungulate works out to be 65% to 35% respectively (Chellam, 1993). This ratio, though may not be representative for whole Gir as I expect the ratio to be otherwise in sanctuary west, still gives an idea about the tremendous changes which have taken place in last two decades. The domestic livestock still contributes significantly to the overall diet of lions and concerted efforts should be made by managers to bring this down as livestock being an easy prey with higher probability of being available to lions, the lion densities must be operating at much higher level compared to what they would have been otherwise. Moreover Gir had a long established management practice of livestock baits being offered to lions in substantial number. Needless to add here, this practice must have had a very strong impact on cub survival in Gir and therefore this reasoning that lion population is operating at higher levels.

8.6 MALDHARIS AND LIVESTOCK GRAZING: Maldharis and their livestock population have been inhabiting Gir approximately the last 150 years (J.A.K. Pers. obser.) and their existence in Gir in past has been perceived differently by different people. While one section believes that over the years Maldharis have become part and parcel of Gir ecosystem and their total removal will have negative impact on lions and ungulate populations , the other section regards this totally baseless and it perceives presence of Maldharis as source of disturbance, degradation and overall threat to conservation of Gir and its lions. Initially there were around 137 nesses having 6700 maldharis located all over Gir with a domestic livestock population of 25,000. However 1972 onward, nearly 63 nesses were shifted outside the peripheries of Gir forest by GDF on the recommendations of Berwick (1974). As such Berwick (1974) could not find any competition for forage between wild ungulate and domestic livestock. However he still perceived the total number of domestic livestock well above the carrying capacity of Gir and that was the main reasons behind the shifting of a large number of nesses from Gir. The shifting of Maldharis and reduction in livestock number has as such had a positive impact on ungulate populations and grass production. There are at present about 2200 Maldharis living in 74 nesses with a livestock population of about 14000. GFD plans to shift all these nesses and their livestock populations outside Gir as their presence is still perceived harmful to Gir vegetation and animal population. The first maldharis shifting program has met with very limited success and the maldharis were not successful in adopting the stall feeding and agriculture. The maldharis inside Gir, are not keen on further shifting program. However the present proposal is considered to have taken care of the shortcomings of the previous one (B.J. Pathak, pers. comm.) and it is expected that maldharis should benefit greatly in terms of better living conditions and earning from livestock population. The point which needs more attention from researchers is whether it is the interest of Gir to shift the maldharis and their livestock or not? My studies certainly do show a negative influence of livestock grazing on ungulate populations and the present level of livestock biomass certainly needs to be brought down in both management units to at least 50%. However it is too premature and hazardous to plan the total shifting of maldharis without really knowing the implications. Firstly the livestock populations still contribute significantly to lions diet and secondly in objective sense maldharis influence the Gir ecosystem by lopping and grazing. While the lopping is very marginal and restricted to only dry season, the level of grazing is severe only inside sanctuary east. Both factors if above a certain limits can have a totally negative impact, but if brought down within reasonable limits can be beneficial for ungulate populations. Therefore the whole issue of maldharis and livestock should be viewed as a problem of regulations rather than eradications. I feel that certain amount of biotic interference will always be required inside Gir to keep the vegetation suitable to ungulate populations. It lopping helps in checking of browse line within the reach of most ungulates and disturbance favours the growth of thorny *Acacia* and *Zizyphus* species, then it should be retained and exploited to the advantage of ungulate populations in Gir. Similarly grazing if allowed within limits creates optimal grazing regimen for a species like chital whose diet predominantly consist of grass rather than the browse. Moreover regeneration of trees and shrubs inside Gir was found to be highest in sanctuary west where moderate grazing still takes place. The point which needs to be emphasized here is that no shifting of maldharis should take place in haste and a study exclusively designed to investigate the dynamics of grazing and lopping should be taken before such a decision. In case the findings are not otherwise then shifting of maldharis should not take place and should be managed so that man and wildlife can coexist on long term basis. Managers, I feel can achieve much more by limiting the number of livestock per ness and relocating the nesses from valleys and riverine forest to optimize and to achieve uniform grazing pressure.

8.7 FIRE: The role of fire in Gir is again very controversial and debatable and has not been evaluated in past in relation to ungulate populations. So far the managers have been following a policy of total fire protection inside Gir and every year considerable time and money is spent in creating fire lines along the 700 km of road network. All most all fires have so far been accidental except few which have been set deliberately by the wood cutters. My preliminary observations suggest that repeated fire creates savannah conditions in Gir and promotes thorny and fire resistant tree species. At the same time, early fires during december result in growth of fresh grass, much needed food resource by chital at that time. I strongly feel that a study should be undertaken to exclusively investigate the role of fire in Gir in relation to vegetation as well as ungulate populations and if possible, managers should try to use it as management tool.

8.8 ADMINISTRATIVE PROBLEMS: At present three highways and a railway track pass through Gir which result in considerable disturbance to wildlife of Gir. Apart from this, there are four big temples inside Gir which attract nearly 70,000 devotees on annual basis. Lack of necessary political will and considering the overall state of affairs in India regarding religion, managers have faced numerous problems in checking the activities of people related to the temples. These temples are a constant source of disturbance which needs to be minimised at any cost. Moreover the movement of people inside Gir whether it is for collection of fruits or for any other things needs to be minimised at all cost. There is ample scope inside Gir to strengthen the protection all around Gir.

8.9 LOCAL VILLAGES AND THEIR LIVESTOCK POPULATIONS :

No conservation movement in India can be successful unless it takes into account the aspiration of local people and unless alternative source of energy and source of grass in provided, it does not seem justified to enforce the law strictly against grazing and fire wood collection. In recent times, the hostility between park managers and local people has grown due to lion straying problem. Gir can never afford to have such hostility from local people and there is a genuine need for an overall ecodevelopment program all around Gir to make people more aware about conservation of Gir. Development of pastures for grazing, nature education program and by providing alternative source of fuel in nearly 72 villages which are located on peripheries of Gir would go a long way in helping the overall conservation of Gir.

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APPENDIX - I

Table 60. Percentage frequency of different plant species (>6m height) in different stratum of Gir sanctuary.

Plant species	S(West)	N.P.	S(East)
Acacia nilotica	40.0	1.1	9.3
Acacia catechu	53.3	3.3	68.7
Acacia chundra	6.6	13.3	9.3
Acacia leucophloea	1.1	2.2	3.1
Acacia senegal	13.3	--	6.25
Aegle marmalos	7.7	2.2	--
Albizia lebbeck	4.4	--	--
Anogeissus latifolia	--	--	68.7
Azadirachta indica	--	1.1	--
Bombax ceiba	2.2	1.1	--
Bauhinia racemosa	5.5	16.6	--
Boswellia serrata	5.5	16.6	28.1
Butea monosperma	6.6	6.6	6.2
Bridelia retusa	1.1	1.1	--
Cassia fistula	1.1	17.7	--
Delbergia latifolia	4.4	13.1	--
Diospyros melonoxylon	12.2	6.6	15.6
Emblica officinalis	8.8	18.8	15.6
Ficus religiosa	1.1	3.3	--
Ficus bengalensis	--	2.2	3.1
Grewia tiliaefolia	8.8	30.0	--
Gmelina arborea	1.1	--	--

Gruga pinnata	2.2	3.3	--
Holarrhena antidysentrica	13.3	14.4	--
Holoptelia integrifolia	3.3	--	--
Lannea coromandelica	5.5	16.6	9.3
Manilkara hexandra	1.1	--	--
Mitragyna parvifolia	3.3	--	--
Milusa tomentosa	3.3	9.9	--
Morinda tinctorea	2.2	2.2	--
Moringa oliefera	1.1	--	--
Pongammia pinnata	3.3	1.1	--
Pterocarpus marsupium	2.2	6.6	--
Sapindois pinnata	--	2.2	--
Sapindus emarginatus	2.2	--	--
Schrebera swietenioides	5.5	1.1	3.1
Sterculia urens	3.3	4.4	--
Soymida febrifuga	2.2	2.2	25.0
Syzyguim rubicundum	2.2	1.1	--
Tectona grandis	91.1	91.1	--
Terminalia bellerica	--	8.8	--
Terminalia crenulata	13.3	33.3	62.5
Wrightia tinctoria	26.6	35.5	3.1
Xeromphis uligionosa	6.6	4.4	3.1
Zizyphus mauritiana	31.1	11.1	3.1
Zizyphus xylopyros	12.2	--	--

Table 61. Percentage frequency of different plant species (2-6m height) in different stratum of Gir sanctuary.

Plant species	S(West)	N.P.	S(East)
Acacia catechu	25.5	23.3	43.7
Acacia chundra	9.7	11.1	6.25
Acacia leucophloea	11.1	10.0	18.7
Acacia nilotica	21.1	23.3	25.0
Acacia senegal	3.3	--	--
Aegle marmalos	12.2	2.2	--
Albizia lebbeck	2.1	--	--
Anogeissus latifolia	--	--	53.3
Balenites aegyptica	3.3	2.2	12.5
Bombax ceiba	1.1	--	--
Bauhinia racemosa	22.2	20.0	28.1
Boswellia serrata	--	3.3	6.25
Bridelia retusa	1.1	--	--
Butea monosperma	5.5	1.1	12.5
Carissa opaca	5.5	3.3	9.3
Cassia fistula	1.1	17.7	--
Clerodendrom multiflorum	1.1	--	--
Diospyros melonoxylon	4.4	5.5	9.3
Ehretia laevis	3.1	--	--
Emblica officinalis	7.7	7.7	15.6
Ficus religiosa	--	--	3.1

Flaucortia indica	6.6	3.1	1.1
Grewia tiliaefolia	10.0	23.3	12.5
Helicteres isora	41.1	68.8	3.1
Holarrhena antidysentrica	27.7	34.4	3.1
Holoptelia integrifolia	--	1.1	--
Ixora arborea	1.1	--	--
Lannea coromandelica	6.6	5.5	6.25
Manilkara hexandra	1.1	--	--
Mitragyna parvifolia	1.1	--	--
Milusa tomentosa	1.1	5.5	--
Morinda tinctorea	2.2	2.2	--
Sapindois pinnata	--	1.1	--
Schrebera swietenioides	3.3	--	--
Securineja leucopyros	5.5	2.2	9.3
Sterculia urens	--	--	3.1
Soymuda febrifuga	1.1	4.4	--
Syzygium rubicundum	--	2.2	--
Tectona grandis	51.5	27.7	--
Terminalia crenulata	15.5	15.5	43.7
Terminalia bellerica	1.1	--	--
Wrightia tinctoria	44.4	43.3	15.6
Xeromphis spinosa	34.4	14.4	3.1
Zizyphus oenoplea	5.5	--	3.1
Zizyphus xylopyros	26.6	1.1	3.1

Table 62. Percentage frequency of different plant species (1-2m height) in different stratum of Gir sanctuary.

Plant species	S(West)	N.P.	S(East)
Acacia catechu	3.3	18.8	21.8
Acacia chundra	--	1.1	--
Acacia leucophloea	4.4	5.5	6.25
Acacia nilotica	10.0	--	28.1
Acacia senegal	2.2	--	--
Aegle marmalos	21.1	7.7	--
Albizia procora	--	1.1	--
Anogeissus latifolia	--	--	43.7
Balenites aegyptica	3.3	--	18.7
Boswellia serrata	--	2.2	--
Bauhinia racemosa	7.7	23.3	13.3
Butea monosperma	--	--	3.1
Capparis sepiaria	10.0	15.5	9.3
Carissa opaca	1.1	2.2	6.25
Cassia fistula	3.3	14.4	--
Clerodendrom multiflorum	2.2	--	--
Delbergia latifolia	1.1	3.3	--
Dichrostachys cineria	13.3	3.3	18.7
Diospyros melonoxylon	5.5	3.3	--
Emblica officinalis	4.4	8.8	15.6
Ficus racemosa	--	1.1	--

Flaucortia indica	5.5	4.4	--
Grewia tiliaefolia	15.5	26.6	6.2
Gruga pinnata	1.1	--	3.1
Helicteres isora	46.6	70.0	12.5
Holarrhena antidysentrica	12.2	28.8	--
Holoptelia integrifolia	1.1	2.2	--
Lannea coromandelica	1.1	1.1	3.1
Milusa tomentosa	--	1.1	--
Mitragyna parvifolia	2.2	--	3.1
Morinda tinctoria	5.5	--	--
Pongammia pinnata	1.1	--	--
Sapindus emerginatus	1.1	--	--
Securineja leucopyros	5.5	--	6.6
Sterculia urens	2.2	--	--
Soymida febrifuga	--	5.5	--
Syzygium rubicundum	--	2.2	--
Tectona grandis	34.4	24.4	--
Terminalia crenulata	7.7	10.0	28.1
Terminalia bellerica	1.1	1.1	--
Wrightia tinctorea	56.6	53.3	3.1
Xeromphis spinosa	27.7	12.2	--
Zizyphus mauritiana	15.5	8.8	40.6
Zizyphus oenoplea	1.1	--	--
Zizyphus xylopyros	11.1	--	--

Table 63. Percentage frequency of different plant species (0-1m height) in different stratum of Gir sanctuary.

Plant species	S(West)	N.P.	S(East)
Acacia catechu	37.7	22.2	40.6
Acacia leucophloea	22.2	23.3	37.5
Acacia nilotica	22.2	3.3	21.8
Acacia senegal	6.6	--	--
Aegle marmalos	20.0	11.1	--
Albizia lebbeck	2.2	2.2	--
Albizia procora	1.1	2.2	--
Anogeissus latifolia	--	--	40.6
Balanites aegyptica	13.3	1.1	34.3
Bombax ceiba	1.1	1.1	--
Bauhinia racemosa	51.1	66.6	34.3
Boswellia serrata	3.3	6.6	3.1
Bridelia retusa	1.1	--	--
Butea monosperma	2.2	2.2	12.5
Capparis sepiaria	65.5	43.3	25.0
Carissa opaca	20.0	12.2	6.25
Cassia fistula	17.7	18.8	--
Delbergia latifolia	2.2	3.3	--
Dichrostachys cineria	24.4	--	34.3
Diospyros melonoxylon	38.8	25.5	28.1

Emblica officinalis	13.3	15.5	21.8
Ficus religiosa	1.1	--	--
Ficus racemosa	--	1.1	--
Flaucortia indica	16.6	16.6	6.25
Grewia tiliaefolia	12.7	13.3	15.6
Holarrhena antidysentrica	30.0	33.3	--
Helicteres isora	61.6	64.4	21.8
Holoptelia integrifolia	1.1	--	--
Lannea coromandelica	1.1	--	--
Manilkara hexandra	3.3	--	--
Milusa tomentosa	--	4.4	--
Mitragyna parvifolia	2.2	3.3	--
Morinda tinctoria	16.6	3.3	6.25
Pongammia pinnata	2.2	--	--
Sapindus emerginatus	5.5	10.0	--
Securineja leucopyros	24.4	6.6	9.3
Sehrebera swietenioides	2.2	1.1	--
Sterculia urens	--	1.1	--
Soymida febrifuga	1.1	5.5	10.5
Syzygium rubicundum	1.1	1.1	--
Tamarindus indica	1.1	--	--
Tectona grandis	40.0	22.2	--
Terminalia bellerica	2.2	2.2	--

Terminalia crenutala	5.5	14.4	21.8
Wrightia tinctorea	56.6	41.1	6.25
Xeromphis spinosa	26.6	20.0	--
Xeromphis uligionosa	3.3	1.1	--
Zizyphus mauritiana	3.0	14.4	18.7
Zizyphus oenoplea	11.1	--	3.1

Table 64 Tree densities in (>6 m) in different stratum of Gir.

Plant Species	S.W.	N.P.	S.E.
Acacia catechu	24.5	14.5	20.5
Acacia chundra	--	3.2	0.78
Acacia leucophloea	0.48	1.03	0.71
Acacia nilotica	8.1	1.1	2.2
Acacia senegal	11.9	--	2.5
Aegle marmelos	3.4	0.69	--
Albizia lebbeck	1.2	--	--
Albizia procera	1.7	0.90	--
Bauhinia racemosa	9.0	4.3	--
Bombax ceiba	3.0	0.32	--
Boswellia serrata	2.9	5.8	7.0
Butea monosperma	2.01	5.8	2.6
Cassia fistula	0.25	3.5	--
Delbergia latifolia	3.4	2.7	--
Diospyros melanoxylon	8.8	3.3	4.9
Emblica officinalis	2.9	6.4	3.3
Ficus religiosa	0.30	1.4	--
Gruga pinnata	1.1	2.5	--
Grewia tiliaefolia	6.1	25.4	0.43
Holarrhena antidysenterica	13.09	4.1	--
Holoptelia integrifolia	1.1	--	--
Lannea coromandelica	3.2	6.05	0.43

Milusa tomentosa	0.61	3.86	--
Mitragyna parvifolia	0.70	--	--
Morinda tinctoria	0.60	0.79	--
Moringa oliefera	0.98	--	--
Pongamia pinnata	--	0.075	--
Pterocarpus marsupium	1.2	106.0	32.6
Rendia dumetorum	1.2	2.06	--
Tectona grandis	126.7	165.4	--
Terminalia crenulata	5.4	12.7	20.5
Wrightia tinctoria	17.2	21.09	1.4
Zizyphus mauritiana	13.6	3.8	2.7
Zizyphus xylopyros	3.9	--	--
Goni	--	5.6	--

Table 65 Tree densities in (2-6 m) in different stratum of Gir.

Plant Species	S.W.	N.P.	S.E.
Acacia catechu	13.4	14.5	24.1
Acacia chundra	5.0	2.9	2.1
Acacia leucophloea	5.2	3.9	8.7
Acacia nilotica	11.1	1.3	16.4
Acacia pinnata	0.36	--	--
Acacia senegal	0.85	--	--
Aegle marmelos	10.5	0.98	--
Albizia lebbeck	1.3	--	--
Anogeissus latifolia	--	--	97.7
Bauhinia racemosa	10.4	13.6	6.3
Bombax ceiba	3.5	--	--
Butea monosperma	6.9	0.46	0.71
Capparis sepiaria	19.6	16.3	--
Carissa opaca	36.1	4.3	13.5
Cassia fistula	11.9	6.4	--
Dichrostachys cineria	17.6	0.60	18.9
Diospyros melanoxylon	3.9	6.05	4.8
Ehretia leavis	10.2	--	--
Emblica officinalis	4.2	7.01	3.6
Flaucortia indica	1.9	0.93	6.2
Grewia tiliaefolia	6.9	26.1	7.3
Helicteres isora	69.3	406.1	2.1

Holarrhena antidysenterica	49.2	82.5	37.5
Lannea coromandeliea	5.4	1.8	3.5
Rendia dumetorum	53.8	19.09	0.53
Securinega leucopyros	2.9	0.15	3.09
Tectona grandis	34.5	22.2	--
Terminalia crenulata	11.07	6.8	22.2
Wrightia tinctoria	49.01	75.5	9.4
Zizyphus mauritiana	26.8	4.1	11.8
Zizyphus xylopyros	16.25	1.9	0.4

Table 66 Tree densities in (1-2 m) in different stratum of Gir.

Plant Species	S.W.	N.P.	S.E.
Acacia catechu	1.8	14.09	12.9
Acacia leucophloea	1.07	1.8	3.9
Acacia nilotica	4.3	--	26.8
Acacia senegal	0.71	--	--
Aegle marmelos	13.9	5.4	--
Anogeissus latifolia	--	--	35.7
Balanites aegyptica	0.71	1.08	8.9
Bauhinia racemosa	5.4	10.1	7.2
Capparis sepiaria	2.8	9.03	6.9
Carissa opaca	0.7	1.4	1.9
Cassia fistula	3.5	6.5	--
Delbergia latifolia	0.71	1.4	--
Dichrostachys cineria	3.6	1.4	10.9
Diospyros melanoxylon	2.8	1.08	9.9
Flaucortia indica	2.7	1.8	--
Grewia tiliaefolia	5.8	11.5	2.9
Helicteres isora	88.6	200.6	5.9
Holarrhena antidysenterica	29.2	31.09	--
Morinda tinctoria	2.4	--	--
Pongamnia pinnata	0.35	--	--
Rendia dumetorum	12.9	5.7	--
Sapindus emerginatus	0.72	--	--

Securinega lencopyros	--	3.9	0.72
Sterculia urens	0.72	0.36	--
Tectona grandis (coppice)	13.7	8.3	--
Tectona grandis (regeneration)	5.4	3.5	--
Terminalia bellerica	0.71	0.36	--
Terminalia crenulata	4.3	4.3	25.8
Wrightia tinctoria	37.6	50.6	5.9
Zizyphus mauritiana	7.9	4.3	17.8

Table 67 Tree densities in (0-1 m) in different stratum of Gir.

Plant Species	S.W.	N.P.	S.E.
Acacia catechu	17.2	40.8	17.6
Acacia leucophloea	18.8	8.3	18.8
Acacia nilotica	954.30	0.71	17.8
Acacia senegal	5.4	--	--
Aegle marmelos	52.4	11.2	--
Albizia lebbeck	0.36	0.71	--
Albizia procera	0.36	0.71	--
Anogeissus latifolia	--	--	67.6
Balanites aegyptica	17.0	27.8	114.3
Bauhinia racemosa	57.5	53.5	34.2
Bombax ceiba	0.36	0.36	--
Boswellia serrata	1.07	7.2	0.96
Butea monosperma	0.72	0.72	4.9
Capparis sepiaria	89.7	53.5	26.8
Carissa opaca	10.8	7.9	11.9
Cassia fistula	7.5	7.9	--
Delbergia latifolia	0.72	2.1	--
Dichrostachys cineria	45.1	0.36	11.9
Diospyros melanoxylon	118.9	41.9	118.3
Ehretia leavis	7.6	--	--
Flaucortia indica	7.22	7.2	1.9
Grewia tiliaefolia	4.6	6.5	5.9

Helicteres isora	83.2	126.03	10.9
Holarrhena antidysenterica	185.2	40.8	--
Morinda tinctoria	6.1	1.8	--
Rendia dumetorum	12.9	13.7	--
Sapindus emerginitus	5.05	4.3	--
Tectona grandis (coppice)	6.86	3.6	--
Tectona grandis (regeneration)	23.8	6.5	--
Terminalia crenulata	1.8	5.0	14.9
Wrightia tinctoria	41.5	27.1	7.9
Zizyphus mauritiana	15.9	6.1	6.9

Table 68. Tree species densities in different habitat types (> 6 m height).

Plant species	TAZW	TBSW	THW	RW	MTW	ALTCW	ALBLW
Acacia catechu	16.8	21.6	13.1	--	8.07	29.6	11.7
Acacia nilotica	12.2	1.6	44.8	--	--	3.6	1.9
Acacia senegal	31.7	0.21	31.4	--	--	2.6	2.6
Aegle marmelos	0.8	2.3	--	--	3.5	--	--
Anogeissus latifolia	--	--	15.1	--	--	40.6	23.1
Albizia lebbeck	--	0.85	--	--	--	--	--
Albizia procera	--	1.6	--	--	--	--	--
Bauhinia racemosa	1.0	2.9	1.9	--	7.8	--	--
Bombax ceiba	1.07	0.43	--	--	--	--	--
Boswellia serrata	--	5.9	--	--	--	3.1	11.8
Butea monosperma	1.6	2.4	--	--	25.5	1.6	2.2
Capparis sepiaria	--	0.96	--	--	--	--	--

Cassia fistula	0.84	1.2	--	--	11.3	--	--
Delbergia latifolia	--	2.6	--	--	0.93	--	--
Diospyros melanoxylon	0.51	3.4	11.2	--	11.3	3.06	2.1
Emblica officinalis	3.6	5.07	--	--	4.8	2.9	4.2
Ficus bengalensis	--	--	--	2.2	--	--	--
Grewia tiliaefolia	5.2	7.8	--	--	29.4	0.93	--
Holarrhena antidysenterica	--	6.3	--	--	16.3	--	--
Holoptelia integrifolia	--	--	--	9.4	--	--	--
Lannea coromandelica	--	--	--	--	--	1.2	--
Pongamia pinnata	--	--	--	11.3	--	--	--
Rendia dumetorum	3.6	0.97	--	15.3	7.07	1.2	--
Sapindus emarginatus	--	0.56	--	9.3	--	--	--
Soymida febrifuga	--	1.5	--	--	--	--	--
Sterculia urens	--	1.5	--	--	--	--	--
Syzyguim rubicundum	--	--	--	15.3	--	--	--

Tectona grandis	116.5	157.8	--	84.0	141.8	--	--
Tereminalia crenulata	4.6	9.1	0.97	--	19.0	25.4	13.1
Terminalia bellerica	--	--	--	--	5.6	--	--
Wrightia tinctoria	--	20.3	--	--	36.3	--	3.1
Zizyphus mauritiana	83.6	5.07	8.5	44.0	3.4	2.4	--
Zizyphus xylopyros	1.0	2.4	--	--	--	--	--

Table 69 Shrub species densities in different habitat types (shrub category 2-6 m)

Plant species	TAZW	TBSW	THW	RW	MTW	ALTCW	ALBLW
Acacia catechu	3.8	17.6	6.7	--	--	25.7	23.8
Acacia nilotica	25.5	0.97	22.7	--	9.7	29.06	6.1
Acacia leucophloea	8.5	3.5	--	--	9.7	10.06	8.5
Acacia senegal	3.03	--	--	--	--	--	--
Aegle marmelos	7.8	6.3	--	--	3.5	--	--
Anogeissus latifolia	--	--	--	--	--	36.3	159.4
Albizia lebbeck	0.96	0.72	--	--	--	--	--
Balanites aegyptica	0.26	1.6	--	--	--	7.3	24.3
Bauhinia racemosa	31.6	9.4	10.8	--	--	8.9	4.2
Boswellia serrata	--	0.21	--	--	--	0.91	1.4
Butea monosperma	2.8	6.9	--	--	3.1	6.4	3.4

Capparis sepiaria	12.8	5.1	--	--	69.3	--	--
Cassia fistula	1.6	6.4	--	--	--	--	--
Delbergia latifolia	--	1.2	--	--	--	--	--
Dichrostachys cineria	12.5	2.7	12.2	--	--	24.0	5.8
Diospyros melanoxylon	1.1	3.7	2.8	--	27.6	9.3	0.91
Emblica officinalis	2.8	6.9	--	--	--	5.9	1.8
Grewia tiliaefolia	3.2	19.75	--	5.3	16.1	3.63	12.06
Helicteres isora	26.1	272.3	--	110.3	375.0	--	4.6
Holarrhena antidysenterica	16.07	81.4	--	14.3	29.7	--	80.0
Holoptelia integrifolia	--	--	--	--	12.3	--	--
Lannea coromandelica	--	--	--	14.3	--	7.6	--
Rendia dumetorum	43.5	24.6	--	15.3	155.5	--	1.1
Sterculia urens	--	--	--	--	--	4.2	--
Syzyguim rubicundum	--	--	--	5.9	--	--	--

Tectona grandis	38.03	26.8	29.6	44.6	23.6	--	--
Terminalia crenulata	8.6	7.7	--	--	25.3	26.9	20.6
Wrightia tinctoria	31.3	68.2	--	--	66.6	2.06	18.0
Zizyphus mauritiana	45.1	13.5	--	89.6	19.7	11.6	6.3
Zizyphus xylopyros	5.07	8.9	--	--	22.4	--	--

Table 70 Shrub species distribution (1-2 m) in different habitat types

Plant species	TAZW	TBSW	THW	RW	MTW	ALTCW	ALBLW
Acacia catechu	1.1	10.36	4.4	--	--	4.2	21.2
Acacia leucophloea	2.4	0.96	--	10.3	2.8	8.4	--
Acacia nilotica	9.7	0.71	44	--	--	38.1	16.9
Acacia senegal	2.4	--	--	--	--	--	--
Aegle marmelos	26.9	6.5	--	31.6	7.3	--	--
Anogeissus latifolia	--	--	4.5	--	--	21.2	--
Albizia procera	--	0.24	--	--	--	--	--
Balanites aegyptica	--	--	--	--	--	--	4.2
Bauhinia racemosa	3.6	9.3	--	10.3	--	--	9.1
Boswellia serrata	--	0.72	--	--	--	--	--
Capparis sepiaria	3.6	5.5	9.0	--	17.07	10.6	--

Carissa opaca	1.2	0.23	--	31.6	2.3	4.2	--
Cassia fistula	--	--	--	4.5	21.0	7.3	--
Delbergia latifolia	--	1.2	--	--	31.6	--	--
Dichrostachys cineria	1.2	3.12	--	10.3	--	16.9	4.2
Diospyros melanoxylon	--	1.6	--	31.6	--	--	--
Emblica officinalis	3.6	2.4	--	10.3	3.1	8.4	12.7
Grewia tiliaefolia	3.6	8.4	--	10.3	4.8	2.1	4.2
Helicteres isora	26.8	154.9	--	159.0	294.0	4.1	4.2
Holarrhena antidysenterica	18.37	36.1	--	10.3	--	10.6	2.1
Holoptelia integrifolia	--	--	--	10.3	--	--	--
Rendia dumetorum	4.8	10.8	--	--	7.3	--	--
Soymida febrifuga	--	1.6	--	--	--	--	--
Sterculia urens	--	0.71	--	--	--	--	--
Syzyguim rubicundum	--	--	--	10.3	--	--	--

Tectona grandis	19.5	10.5	--	10.3	--	--	--
Terminalia crenulata	1.1	5.06	--	--	4.8	--	42.4
Wrightia tinctoria	23.2	47.9	--	--	46.4	6.1	6.3
Zizyphus mauritiana	3.6	7.4	4.5	74.0	--	21.2	14.0
Zizyphus xylopyros	--	--	--	--	3.1	--	--

Table 71 Shrub species distribution (0-1 m) in different habitat types

Plant species	TAZW	TBSW	THW	RW	MTW	ALTCW	ALBLW
Acacia catechu	56.2	40.26	9.0	--	4.8	19.06	16.9
Acacia leucophloea	7.3	9.8	18.1	21.2	9.7	16.9	23.2
Acacia nilotica	34.2	1.6	--	10.3	41.6	27.5	4.2
Acacia senegal	9.7	0.23	--	53.0	3.1	--	--
Aegle marmelos	105.2	9.9	--	148.3	85.6	--	--
Anogeissus latifolia	--	--	--	--	--	--	65.7
Albizia procera	1.2	0.47	--	--	--	--	--
Balanites aegyptica	14.6	26.7	--	--	3.1	177.9	66.06
Bauhinia racemosa	74.6	56.6	13.5	10.3	22.0	45.5	21.2
Boswellia serrata	--	5.06	--	--	3.1	--	2.1
Capparis sepiaria	96.6	62.4	13.5	286.3	66.07	44.5	2.1

Carissa opaca	11.0	4.5	--	95.3	36.3	--	--
Cassia fistula	9.7	6.5	--	10.3	17.07	--	--
Delbergia latifolia	--	1.6	--	--	3.1	--	--
Dichrostachys cineria	24.5	0.7	13.5	--	3.1	--	--
Diospyros melanoxylon	100.3	56.4	--	63.3	301.1	55.1	12.6
Emblica officinalis	232.2	8.1	4.5	--	7.3	8.4	8.4
Grewia tiliaefolia	6.1	6.9	--	--	14.6	4.2	--
Helicteres isora	47.7	81.5	--	53.0	122.4	8.4	10.6
Holarrhena antidysenterica	216.6	84.1	--	137.0	210.5	--	--
Rendia dumetorum	100.3	18.07	--	10.3	580.3	--	--
Sapindus emerginatus	6.1	2.4	--	--	7.3	--	--
Soymida febrifuga	1.2	3.1	--	--	--	--	--
Sterculia urens	--	0.47	--	--	--	--	--
Syzyguim rubicundum	--	--	--	63.6	--	--	--

Tectona grandis	8.5	5.05	--	10.3	--	--	--
Terminalia crenulata	1.2	3.1	--	--	--	12.8	19.06
Wrightia tinctoria	40.3	52.7	--	31.6	31.7	10.3	4.2
Zizyphus mauritiana	15.8	15.5	9.0	610.0	7.3	10.3	2.1
Zizyphus oenoplea	17.1	1.4	--	--	--	2.1	--
Zizyphus xylopyros	6.1	0.96	--	--	3.1	--	--

APPENDIX - II

Table 72. Details of Number of Nesses, Maldharies and domestic livestock in Gir Lion Sanctuary.

Stratum	No. of Nesses/ Forest Settlement	No. of Livestock	Human Popu- lation	Average No. of Livestock per Ness
Gir(West)	36	5455	1163	151.5
Gir(East)	38	8300	1009	218.4
Gir(West)	9	1308	1674	145.3
Gir(East)	5	1692	1906	338.4

Data from Gir Sanctuary and National Park master plan, 1988.

Table 73. Details of vehicle counts carried out in Gir.

Vehicle count, Summer 1987

Stratum	Transect run	Km coverage	Time	
			A.M.	P.M.
Sanctuary (west)	15	314	153	161
National Park	11	266	144	122
Sanctuary (East)	3	72	27	45
Total	29	65	324	328

Vehicle count, Winter 1988

Stratum	Transect run	Km coverage	Time	
			A.M.	P.M.
Sanctuary (West)	16	321	140	181
National Park	10	218	109	109
Sanctuary (East)	7	140	40	100
Total	33	679	289	390

Vehicle count, Summer 1989

Stratum	Transect run	Km coverage	Time	
			A.M.	P.M.
Sanctuary (West)	10	212	110	102
National Park	19	414	252	162
Sanctuary (East)	11	222	98	124
Total	40	848	460	388

Vehicle Count, Winter 1989

Stratum	Transect run	Km coverage	Time	
			A.M.	P.M.
Sanctuary (West)	31	581	135	446
National Park	17	315	165	150
Sanctuary (East)	3	57	18	39
Total	51	953	318	635

Table 74. Animal sighting per stratum (Number of individuals). Vehicle count, Summer 1987.

Species	Sanctuary (West)	National Park	Sanctuary (East)	Total	Group Seen in 3 Stratum	Mean Group Size
Chital	1562	793	227	2282	505	5.0
Sambar	39	119	2	160	93	1.7
Nilgai	5	8	15	28	11	2.5
Chowsingha	6	18	1	25	22	1.1
Chinkara	0	0	0	0	0	0
Wild boar	7	19	0	25	6	4.1

Table 75. Animal group sightings and mean group size per stratum. Vehicle count, Winter, 1988.

Animal Species	Sanctuary(West)			National Park			Sanctuary(East)			
	Group	Total	Mean Group Size	Group	Total	Mean Group Size	Group	Total	Mean Group Size	Overall Group Size
Chital	212	1415	4.5	216	1044	4.8	99	398	4	4.5
Sambar	22	42	1.9	32	58	1.8	3	5	1.6	1.8
Nilgai	14	35	2.5	12	21	1.7	19	40	2.1	2.1
Chowsingha	17	19	1.1	13	16	1.2	2	3	1.5	1.1
Chinkara	1	3	3	0	0	0	19	34	1.7	1.8
Wild boar	7	24	3.4	8	26	3.2	1	4	4	3.3

Table 76. Group size per stratum of different herbivore species. Summer vehicle count, 1989.

Animal Species	Sanctuary (West)			National Park			Sanctuary (East)			Overall
	Groups	Individuals	Mean Group Size	Groups	Individuals	Mean Group Size	Groups	Individuals	Mean Group Size	
Chital	139	792	5.6	259	1735	6.6	123	878	7.1	6.5
Sambar	6	13	2.1	29	52	1.7	1	3	3	1.8
Nilgai	1	1	0	6	6	1	22	29	1.3	1.2
Chowsingha	0	0	0	1	1	0	3	3	0	0
Chinkara	0	0	0	0	0	0	26	67	2.5	2.5
Wild boar	2	5	0	2	3	0	3	6	0	0

Table 77. Mean Group sizes for Chital and Sambar (A.M. & P.M. figures).

		Summer 1987		Winter 1988		Summer 1989	
		Chital	Sambar	Chital	Sambar	Chital	Sambar
Overall	A.M.	4.8	1.7	4.5	1.7	5.5	1.75
	P.M.	5.2	1.7	4.5	1.8	7.04	1.72
Gir (West)	A.M.	5.3	2	4.6	1.6	4.3	2.2
	P.M.	5.4	1.4	4.5	1.8	6.2	1
National Park	A.M.	4.02	1.6	4.3	1.8	6.0	1.5
	P.M.	3.9	1.8	4.8	2	7.2	1.8
Gir (East)	A.M.	8.25	0	4.4	0	6.1	0
	P.M.	8.4	2	4.01	1.6	7.4	3

Table 78. Animal group sighting per stratum per distance class interval. Vehicle count, Summer 1987.

Distance	Total Chital Frequency				Total Sambar Frequency			
	West	National Park	East	Total	West	National Park	East	Total
0-10	72	41	5	118	5	22	0	27
11-20	88	54	4	146	4	18	0	22
21-30	49	27	6	82	5	6	0	11
31-40	41	27	4	72	4	8	0	12
41-50	22	20	4	46	4	11	1	16
51-60	12	13	2	27	0	2	0	2
61-70	4	3	1	8	0	0	0	0
71-80	2	0	1	3	0	0	0	0
81-90	0	0	0	0	0	0	0	0
91-100	0	0	0	0	0	0	0	0
100+	2	1	0	3	0	3	0	3

Table 79. Animal group sighting per distance class interval. Vehicle count, Summer 1987.

Distance	Chital f	Sambar f	Nilgai f	Chowsingha f	Chinkara f	Wild pig f
0-10	118	27	0	7	0	1
11-20	146	22	5	10	0	3
21-30	82	11	2	4	0	0
31-40	72	12	2	1	0	0
41-50	46	16	2	0	0	1
51-60	27	2	0	0	0	0
61-70	8	0	0	0	0	0
71-80	3	0	0	0	0	0
81-90	0	0	0	0	0	0
91-100	0	0	0	0	0	0
>100	3	3	0	0	0	0
Total	505	93	11	22	0	5

Table 80. Group sighting frequency per stratum data. Vehicle count, Winter 1988.

Class	Chital			Sambar			Nilgai			Chowsingha			Chinkara			Wild boar		
	SW	NP	SE	SW	NP	SE	SW	NP	SE	SW	NP	SE	SW	NP	SE	SW	NP	SE
0-10	113	72	25	12	8	1	5	3	3	5	6	0	0	0	5	4	2	0
10-20	83	37	22	8	2	1	2	2	3	3	3	0	0	0	2	3	1	0
21-30	40	41	11	6	1	0	2	2	0	1	5	0	0	1	3	0	1	0
31-40	41	30	14	1	4	0	3	2	1	2	1	0	0	0	4	1	1	0
41-50	17	6	7	3	4	1	0	3	0	0	1	0	0	0	1	0	0	0
51-60	10	4	7	0	1	0	1	0	2	1	0	0	0	0	0	0	0	0
61-70	5	8	4	1	0	0	0	1	2	1	1	1	0	0	1	1	0	0
71-80	1	2	2	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0
81-90	0	4	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0
91-100	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
100+	2	12	6	0	1	0	1	0	5	0	0	0	0	0	3	0	1	0
Total	212	217	98	31	22	3	14	14	17	13	17	2	0	1	19	9	7	0

Table 81. Animal sighting frequency per distance class interval. Gir vehicle count, Winter 1989.

Class	Chital			Sambar			Nilgai			Chowsingha			Chinkara			Wild boar		
	SW	NP	SE	SW	NP	SE	SW	NP	SE	SW	NP	SE	SW	NP	SE	SW	NP	SE
0-10	32	18	0	4	0	0	1	0	0	0	1	0	0	0	0	0	0	0
11-20	22	18	2	6	0	0	0	0	1	0	0	1	0	0	0	1	0	0
21-30	36	24	2	3	1	0	1	0	1	0	0	0	0	0	1	0	0	0
31-40	29	8	2	4	4	0	1	1	1	0	0	0	0	0	0	2	0	0
41-50	12	4	3	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
51-60	10	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
61-70	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
71-80	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
81-90	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
91-100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
100+	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Total	231	197	12	17	13	0	10	1	4	4	2	2	0	0	5	4	1	1

Table 82. Frequency of sightings per distance class interval of different herbivore species. Gir vehicle count, Summer 1989.

Class	Chital			Sambar			Nilgai			Chowsingha			Chinkara			Wild boar		
	SW	NP	SE	SW	NP	SE	SW	NP	SE	SW	NP	SE	SW	NP	SE	SW	NP	SE
0-10	32	49	29	1	5	0	0	0	3	0	1	1	0	0	8	0	0	1
11-20	33	57	32	0	9	1	0	2	3	0	0	1	0	0	4	1	2	1
21-30	25	31	28	2	9	0	0	0	4	0	0	0	0	0	2	0	0	0
31-40	28	20	23	0	2	0	1	2	3	0	0	0	0	0	4	1	0	1
41-50	13	16	5	0	2	0	0	0	1	0	0	0	0	0	4	0	0	0
51-60	5	8	2	3	0	0	0	1	0	0	0	0	0	0	3	0	0	0
61-70	3	5	1	0	1	0	0	1	0	0	0	0	0	0	1	0	0	0
71-80	1	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
81-90	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
91-100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
100+	0	3	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0
Total	139	257	123	6	29	1	1	6	15	0	1	2	0	0	25	2	2	3

Table 83. Mean sighting distance for different herbivore species (Distance data in m). Gir vehicle count, Summer 1987.

Stratum	Chital	Sambar	Nilgai	Chowsingha	Chinkara	Wild boar
Overall	23.2	24.6	25.9	14.5	-	19
Sanctuary West	22.6	24.5	-	-	-	-
National Park	24.6	24.5	-	-	-	-
Sanctuary East	25.9	-	-	-	-	-

Table 84. Mean sighting distance data for different herbivore species. Vehicle count, Winter 1988.

Stratum	Chital	Sambar	Nilgai	Chowsingha	Chinkara	Wild boar
Overall	23.7	9	38.5	25.2	24.06	27.1
Sanctuary West	19.7	18.2	26.07	-	-	-
National Park	26.6	29.7	32.8	-	-	-
Sanctuary East	29.8	21.6	53.5	-	-	-

Table 85. Data matrix showing mean sighting angle of methods of density estimation for Chital from line transect data.

Stratum	Winter 1988		Summer 1988		Monsoon 1988		Winter 1989	
	M.S.A.	Method	M.S.A.	Method	M.S.A.	Method	M.S.A.	Method
S.W.	38.5 $\pm$22.8	M.H.E.	35.5 $\pm$23.2	M.H.E.	42.8 $\pm$22.2	M.H.E.	36.4 $\pm$21.7	M.H.E.
Raidi	33.3 $\pm$20.9	M.H.E.	35.1 $\pm$23.0	M.H.E.	42.1 $\pm$18.9	M.H.E.	35.1 $\pm$19.1	M.H.E.
Kadeli	33.8 $\pm$19.1	M.H.E.	26.2 $\pm$17.1	G.H.E.	29.0 $\pm$19.7	G.H.E.	42.1 $\pm$24.2	M.H.E.
Panvi	46.6 $\pm$20.2	G.H.E.	52.0 $\pm$26.9	G.H.E.	57.1 $\pm$22.0	G.H.E.	29.3 $\pm$19.5	G.H.E.
N.P.	48.6 $\pm$25.2	G.H.E.	33.6 $\pm$22.3	M.H.E.	45.5 $\pm$20.9	G.H.E.	45.0 $\pm$21.2	M.H.E.
Ambla	55.0 $\pm$26.2	G.H.E.	37.6 $\pm$21.8	M.H.E.	39.0 $\pm$9.6	M.H.E.	45.0 $\pm$21.2	M.H.E.
Junwania	44.6 $\pm$25.5	M.H.E.	29.1 $\pm$23.7	G.H.E.	48.3 $\pm$24.1	M.H.E.	--	
Chodavadi	--		--		--		--	
S.E.	49.0 $\pm$33.1	G.H.E.	46.8	G.H.E.	--		--	
Leria	25	G.H.E.	--		--		--	
Rajsthali	55.0 $\pm$34.8	G.H.E.	46.8	G.H.E.	--		--	

M.H.E. Modified Hayne's Estimator G.H.E. Generalized Hayne's Estimator

Table 86. Total population estimates of different species in Gir (Forest department figures).

Animal species	1974	1979	1985
Lion	180	205	239
Leopard	155	161	201
Hyaena	74	84	192
Chital	4514	8431	10466
Sambar	707	708	772
Nilgai	1528	2036	2031
Chowsingha	378	1042	1063
Chinkara	165	330	331
Wild boar	1922	2036	2212
Langurs	3938	6958	6912

Waterhole counts for ungulates

Pugmark census and various other methods for carnivores species.

Table 87. Individual transect densities in different stratum for Chital and Sambar. King Census method. Vehicle count, Summer 1987.

Sl. No.	Transect (1987)	Distance	Time	No.of Chital	Density	No.of Sambar	Density
Sanctuary West							
1.	Dadia to Khokhra Naka	21	P.M.	167	104.3	5	2.1
2.	Dadia to Khokhra Naka	21	A.M.	109	99	5	1.5
3.	Khokhra Naka to Dadia	21	A.M.	126	62.6	0	0
4.	Khokhra Naka to Dadia	21	P.M.	117	78	2	1.2
5.	Dudhala Road to Sarasia Guna	7	P.M.	14	28.5	0	0
6.	Dadia Naka to Raidi	24	A.M.	76	40	0	0
7.	Dedakdi to Raidi	25	P.M.	62	51.6	1	.5
8.	Dadia Ness to Bapuwali Tali	20	A.M.	98	81	2	.5
9.	Bapuwali Tali to Dadia Ness	21	P.M.	191	127.3	0	0
10.	Ratanguna to Bhamba Phor	25	P.M.	82	48.2	7	3.3
11.	Bhamba Phor to Ratanguna	25	A.M.	139	77.2	0	0
12.	Kamleshwar to Kutia	18	A.M.	64	45.7	3	3.4
13.	Kutia to Kamleshwar	18	P.M.	56	43	3	2.1
14.	Ratanguna to Pilipat	26	A.M.	145	90.6	5	4.1
15.	Ratanguna to Pilipat	23	P.M.	116	89.2	1	.9

National Park							
16.	Devkunia to Janvadla	22	A.M.	36	32.7	15	10
17.	Kankai Naka to Devadunger	27	A.M.	82	45.5	13	7.6
18.	Kankai Naka to Devadunger	27	P.M.	42	30	22	15.7
19.	Janvadla to Chodavadi	23	P.M.	73	38.4	10	13.6
20.	Khokhra to Kankai Naka	29	P.M.	49	27.2	7	3.04
21.	Kankai Naka to Khokhra	29	A.M.	99	52.1	4	.9
22.	Chodavadi to Janvadla	23	A.M.	130	65	2	1.8
23.	Dhabala to Shirvan	21	P.M.	77	48.1	13	13
24.	Shirvan to Dhabala	21	A.M.	64	40	5	2.7
25.	Shirvan to Karamdari	22	A.M.	44	27.5	19	10
26.	Janvadla to Devkunia	22	P.M.	47	33	9	3.9
Sanctuary East							
27.	Bhimchas to Bhanej	23	P.M.	135	43.5	2	.6
28.	Bhimchas to Bhanej	27	A.M.	27	27.5	0	0
29.	Bhimchas to Jamvali	22	P.M.	26	16.2	0	0

Table 88. Kelker belt transect method (Individual transect densities in different stratum). Vehicle count, Summer 1987.

Sl. No.	Transect (1987)	Distance	Time	No.of Chital	Density	No.of Sambar	Density
Sanctuary West							
1.	Dadia to Khokhra Naka	21	P.M.	63	75	1	1.1
2.	Dadia to Khokhra Naka	21	A.M.	75	89.2	0	0
3.	Khokhra Naka to Dadia	21	A.M	. 64	76.1	0	0
4.	Khokhra Naka to Dadia	21	P.M.	55	65.4	1	1.1
5.	Dudhala Road to Sarasia Guna	7	P.M.	9	32.1	0	0
6.	Dadia Naka to Raidi	24	A.M.	26	27.08	5	5.2
7.	Dedakdi to Raidi	25	P.M.	41	41	0	0
8.	Dadia Ness to Bapuwali Tali	20	A.M.	74	88.09	0	0
9.	Bapuwali Tali to Dadia Ness	21	P.M.	104	123.09	0	0
10.	Ratanguna to Bhamba Phor	25	P.M.	82	82	0	0
11.	Bhamba Phor to Ratanguna	25	A.M.	41	41	2	2
12.	Kamleshwar to Kutia	18	A.M.	17	23.6	2	2.7
13.	Kutia to Kamleshwar	18	P.M.	38	52.7	-	0
14.	Ratanguna to Pilipat	26	A.M.	59	64.1	5	5.4
15.	Ratanguna to Pilipat	23	P.M.	78	84.7	1	1.08

National Park							
16.	Devkunia to Janvadla	22	A.M.	24	27.2	7	7.9
17.	Kankai Naka to Devadunger	27	A.M.	44	40.7	7	6.48
18.	Kankai Naka to Devadunger	27	P.M.	29	26.85	17	15.7
19.	Janvadla to Chodavadi	23	P.M.	44	47.8	10	10.8
20.	Khokhra to Kankai Naka	29	P.M.	32	27.5	5	4.3
21.	Kankai Naka to Khokhra	29	A.M.	48	41.3	1	.86
22.	Chodavadi to Janvadla	23	A.M.	31	33.6	2	2.1
23.	Dhabala to Shirvan	21	P.M.	25	29.7	2	2.3
24.	Shirvan to Dhabala	21	A.M.	53	63.09	9	10.7
25.	Shirvan to Karamdari	22	A.M.	28	31.8	5	5.6
26.	Janvadla to Devkunia	22	P.M.	14	15.9	5	5.6
Sanctuary East							
27.	Bhimchas to Bhanej	23	P.M.	48	52.1	0	0
28.	Bhimchas to Bhanej	27	A.M.	24	26	0	0
29.	Bhimchas to Jamvali	22	P.M.	18	20.4	0	0

Table 89. Individual transect densities for Chital by Fourier series estimator (Grouped & truncated data), Summer 1987.

Sl. No.	Transect	Density	S.E.	% Coff. of Var.	95% C.L.
Sanctuary West					
1.	Dadia to Khokhra Naka	91.2	32.4	257.04	63.8
2.	Dadia to Khokhra Naka	95.4	22.4	151.04	44.16
3.	Khokhra Naka to Dadia Ness	87.7	20.6	125.6	40.8
4.	Khokhra Naka to Dadia Ness	78.3	18.45	107.5	36.4
5.	Dudhala Road to Sarasyaguna	32.6	33.5	474.7	66.2
6.	Dadia Ness to Bapuwalitali	72.1	19.9	159.6	39.3
7.	Baputali to Dadia Ness	127.4	28.9	164.7	58.8
8.	Ratanguna to Pilipat	83.5	20.6	125.9	40.6
9.	Ratanguna to Pilipat	80.6	22.6	162.9	44.6
10.	Bhambaphor to Ratanguna	72.8	20.1	182.8	39.6
11.	Ratanguna to Bhambaphor	44.6	14.8	161.7	29.7
12.	Kamleshwar to Kutia	33.3	15.8	155.7	30.8
13.	Kutia to Kamleshwar	39.5	12.9	123.5	25.9
14.	Dadi Naka to Raisli	36.6	11.2	144.7	22.09
15.	Dedakdi to Dadia Naka	45.9	15.5	140.6	30.7

National Park					
16.	Janvadla to Chodavadi	35.7	10.5	127.2	21.4
17.	Chodavadi to Janvadla	47.1	18.5	208.8	36.4
18.	Shirvan to Karamdari	23.5	8.3	112.8	17.05
19.	Devkunia to Janvadla	32.3	11.4	108.3	22.8
20.	Janvadla to Devkunia	30.24	9.72	88.2	19.6
21.	Khokhra Naka to Kankai Naka	24.5	9.3	159.1	18.8
22.	Kankai Naka to Khokhra Naka	46.4	12.1	118.8	24.4
23.	Kankai Naka to Devadunger	37.73	9.1	84.7	18.13
24.	Kankai Naka to Devadunger	28.2	12.3	133.2	24.6
25.	Shirvan to Dhabhala	37.59	12.95	122.5	26.04
26.	Dhabhala to Shirvan	42.4	15.9	225.9	31.8
Sanctuary East					
27.	Bhimchas to Bhanej	33.4	22.08	620.1	43.2
28.	Bhimchas to Bhanej	21.3	12.3	479.7	25.4
29.	Bhimchas to Jamvali	21.8	15.08	366.6	30.6

Table 90. Individual transect densities for Chital and Sambar. King Census method. Vehicle count, Winter 1988.

Sl. No.	Transect	Distance	Time	No.of Chital	Density	No.of Sambar	Density
Sanctuary West							
1.	Sudava to Janwadla trunoff	21	P.M.	93	46.2	4	3.07
2.	Bawalwala Chowk to Kankai	19	A.M.	45	43.6	9	4.2
3.	Bawalwala Chowk to Kankai	19	P.M.	92	76.6	4	3.09
4.	Dadia Ness to Khokhra Naka	20	P.M.	132	120	3	9.3
5.	Khokhra Naka to Dadia	20	A.M.	98	96.07	1	.62
6.	Khokhra Naka to Dadia Ness	20	A.M.	139	128.7	2	1.6
7.	Kankai to Khambra	20	P.M.	71	44.3	0	0
8.	Ratanguna to Kansia	21	A.M.	54	54	0	0
9.	Ratanguna to Kansia	21	P.M.	99	76.1	11	9.1
10.	Dadia Naka to Pilipat	22	A.M.	70	43.7	0	0
11.	Dadia Naka to Pilipat	22	P.M.	48	32	5	8.6
12.	Khada Patia to Bhambaphor	19	P.M.	57	67.05	0	0

13.	Bhambaphor to Khada Patia	19	A.M.	42	35	2	3.3
14.	Kutia to Kamleshwar	19	P.M.	125	121.3	9	8.7
15.	Kamleshwar to Kutia	19	A.M.	67	60.9	4	2.6
16.	Khokhra Naka to Dadia Ness	20	P.M.	183	179.4	4	4.1
National Park							
17.	Chodavadi to Shumgora Dam	20	A.M.	109	45.4	6	1.8
18.	Shingora Dam to Chodavadi	20	P.M.	181	95.2	4	1.2
19.	Chodavadi to Munda Chowk	23	A.M.	78	60	9	5
20.	Munda Chowk to Chodavadi	23	P.M.	77	77	3	8.3
21.	Munda Chowk to Sudava	20	P.M.	203	92.2	4	1.2
22.	Sudava Ness to Munda Chowk	20	A.M.	70	76	2	.85
23.	Jamwala to Khokhra	25	P.M.	150	93.7	9	22.5
24.	Khokhra to Jamwala	25	A.M.	108	49.09	1	.83
25.	Patnesar to Devkunia	21	A.M.	29	29	4	2.5
26.	Patnesar to Dekunia	21	P.M.	39	27.8	0	0

Sanctuary East

27.	Bhimchas to Rajsthali	18	P.M.	56	57.7	0	0
28.	Bhanej to Bhimchas	21	P.M.	68	101.4	1	1
29.	Bhimchas to Rajsthali	18	P.M.	26	13.6	0	0
30.	Bhimchas to Rajsthali	18	A.M.	53	27.05	0	0
31.	Kardapan to Tulsi Shyam	24	P.M.	59	25.6	0	0
32.	Bhimchas to Jamwali	19	P.M.	21	19.09	0	0
33.	Bhimchas to Charchowk	21	A.M.	119	37.8	4	2.3

Table 91. Individual transect densities for Chital (Density N per sq km). Kelker belt method. Vehicle, Winter 1988.

Sl. No.	Transect	Distance	No.of Chital	Density
Sanctuary West				
1.	Bawalwala Chowk to Kankai	19	35	46.05
2.	Bawalwala Chowk to Kankai	19	38	65.7
3.	Sudava to Janvadla turnoff	21	39	46.4
4.	Kankai to Khambra	20	38	45.2
5.	Kutia to Kamleshwar	19	84	110.5
6.	Kamleshwar to Kutia	19	47	61.8
7.	Dadia Naka to Pilipat	22	21	23.8
8.	Dadia Naka to Pilipat	22	36	40.9
9.	Ratanguna to Kansia	20	49	61.2
10.	Ratanguna to Kansia	20	64	55
11.	Khada Palia to Bhambaphor	19	28	36.8
12.	Bhambaphor to Khada Palia	19	18	23.6
13.	Khokhra Naka to Dadia Ness	20	78	97.5
14.	Dadia Ness to Khokhra Naka	20	98	122.5
15.	Khokhra to Dadia Ness	20	137	171.1
16.	Khokhra to Dadia Ness	20	92	115
National Park				
17.	Patnesar to Devkunia	21	9	21.4
18.	Patnesar to Devkunia	21	3	7.1
19.	Khokhra to Jamwala	25	22	44
20.	Jamwala to Khokhra	25	62	126

21.	Munda Chowk to Chodavadi	23	28	121.7
22.	Chodavadi to Munda Chowk	23	34	147.8
23.	Munda Chowk to Sudava	20	36	90
24.	Sudava to Munda Chowk	20	8	20
25.	Shingora Dam to Chodavadi	20	70	175
26.	Chodavadi to Shingora Dam	20	38	95
Sanctuary East				
27.	Bhimchas to Rajsthali	18	7	9.7
28.	Bhimchas to Rajsthali	18	23	34
29.	Bhimchas to Rajsthali	18	47	67.8
30.	Kardapan to Tulsi Shyam	24	30	31.8
31.	Bhanej to Bhimchas	21	57	67.8
32.	Bhimchas to Char Chowk	22	28	31.9
33.	Bhimchas to Jamwali	19	10	65.2

Width for S.W. = 20 m
Width for S.E. = 20 m
Width for N.P. = 10 m

Table 92. Individual transect densities for Sambar in different stratum (Density number per sq km). Kelker belt transect. Vehicle count, Winter 1988.

Sl. No.	Transect	Distance	No.of Sambar	Density
Sanctuary West				
1.	Bawalwala Chowk to Kankai	19	1	2.6
2.	Bawalwala Chowk to Kankai	19	2	5.2
3.	Sudava to Jamvadla turnoff	21	0	0
4.	Kankai to Khambra	20	0	0
5.	Kutia to Kamleshwar	19	2	5.2
6.	Kamleshwar to Kutia	19	0	0
7.	Dadia Naka to Pilipat	22	4	9.09
8.	Dadia Naka to Pilipat	22	0	0
9.	Ratanguna to Kansia	21	0	0
10.	Ratanguna to Kansia	21	0	0
11.	Khadopalia to Bhambhaphor	19	0	0
12.	Bhambaphor to Kadapalia	19	1	2.6
13.	Khokhra to Dadia Ness	20	0	0
14.	Dadia to Khokhra	20	3	7.5
15.	Khokhra to Dadia	20	2	5
16.	Khokhra to Dadia	20	1	2.5
National Park				
17.	Patnesar to Devkunia	21	0	0
18.	Patnesar to Devkunia	21	0	0
19.	Khokhra to Jamwala	25	0	0
20.	Jamwala to Khokhra	25	9	18

21.	Munda Chowk to Chodavadi	23	3	6
22.	Chodavadi to Munda Chowk	23	7	15.2
23.	Munda Chowk to Sudava	20	3	7.5
24.	Sudava to Munda Chowk	20	0	0
25.	Shingora Dam to Chodavadi	20	0	0
26.	Chodavadi to Shingora Dam	20	0	0
Sanctuary East				
27.	Bhimchas to Rajsthali	18	0	0
28.	*Kardapan to Tulsi Shyam*	24	0	0
29.	Bhaney to Bhimchar	21	0	0
30.	Bhimchas to Char Chowk	22	1	0
31.	Bhimchas to Jamwali	19	0	0
32.	Bhimchas to Rajsthali	18	0	0
33.	Bhimchas to Rajsthali	18	0	0

Width for S.W., S.E. & N.P. = 10 m

Table 93. Individual transect densities of Chital by Fourier series estimator (Grouped and truncated data). Vehicle count, Winter 1988.

Sl. No.	Transect	Density	S.E.	% Coeff. of Var.	95% C.L.
Sanctuary West					
1.	Bawalwala Chowk to Kankai	35.2	20.4	374.4	±40.96
2.	Khokhra Naka to Dadia Ness	44.3	17.6	196.4	±35.03
3.	Bawalwala Chowk to Kankai	144.2	31.1	152.7	±61.5
4.	Khokhra Naka to Dadia Ness	126.1	27.5	116.07	±54.06
5.	Dadia Ness to Khokhra Naka	61.9	16.5	134	±32.5
6.	Kankai to Khambra	56.4	15.8	93.06	±31.3
7.	Ratanguna to Kansia	58.7	15.18	86.4	±30.36
8.	Ratanguna to Kansia	40.59	15.9	162.7	±31.5
9.	Dadia Naka to Pilipat	51.06	14.2	132.02	±28.9
10.	Dadia Naka to Pilipat	51.8	16.2	87.9	±31.9
11.	Khadapatia to Bhambaphor	32.4	14.5	210.09	±28.3
12.	Bhambaphor to Khadapatia	31.7	14.2	205.6	±27.7
13.	Kutia to Kamleshwar	132.5	32.5	123	±64
14.	Kamleshwar to Kutia	49.1	14.04	113.8	±28.4
15.	Khokhra Naka to Dadia Ness	201.1	32.6	78.2	±64.3
16.	Sudava to Jamvadla turnoff	43.4	12.6	103.2	±25.2
National Park					
17.	Chodavadi to Shingora Dam turnoff	45.3	15.1	178.7	±29.7
18.	Shingora Dam to Chodavadi	112.7	27.03	123.4	±53.5
19.	Chodavadi to Munda Chowk turnoff	56.2	15.4	121.6	±31.2

20.Munda Chowk to Sudava Ness	79.4	23.9	116.2	±47.8
21.Munda Chowk to Sudava Ness	108.4	25.2	169.2	±50.1
22.Sudava Ness to Munda Chowk	32.6	16.7	221.4	±33.5
23.Jamwala to Khokhra	83.7	17.5	94.05	±34.1
24.Khokhra to Jamwala	54.03	16.9	112.6	±33.5
25.Patnesar Road to Devkunia	13.5	12.7	394.01	±25.4
26.Patnesar Road to Devkunia	19.5	12.09	244.1	±23.7
<u>Sanctuary East</u>				
27.Bhimchas to Rajsthali	64.8	22.08	157.3	±43.6
28.Bhanej to Bhimchas	98.8	34.1	210.4	±67.1
29.Bhimchas to Rajsthali	12.7	6.5	133.6	±13.3
30.Kardapan to Tulsi Shyam	26.3	7.7	91.7	±15.1
31.Bhimchas to Jamwala	17.7	8.2	109.2	±16.8
32.Bhimchas to Char Chowk	37.7	11.9	147.2	±23.6
33.Bhimchas to Rajsthali	23.7	15.4	282.9	±30.3

Table 94. Individual transect densities for Chital by Fourier series estimator (Grouped and truncated data). Vehicle census, Winter 1989.

Sl. No.	Transect	Density	S.E.	% Coeff. of Var.	95% C.L.
Sanctuary West					
1.	Kamleshwar Patia to Kankai	28.08	18.2	334.3	±35.8
2.	Kankai Naka to Kankai	36.7	18.7	365.04	±37.4
3.	Khokhra to Dadia	24.99	10.2	213.18	±20.4
4.	Khokhra to Dadia	32.5	19.6	424.2	±39.3
5.	Khokhra to Dadia	16.38	15.75	606.6	±32.1
6.	Khokhra to Dadia	17.94	18.72	801.84	±36.6
7.	Khokhra to Dadia	62.2	25.3	336.1	±49.8
8.	Khokhra to Dadia	22.26	12.7	308.4	±25.6
9.	Khokhra to Dadia	50.2	18	219	±36
10.	Khokhra to Dadia	17.7	15.5	657.1	±30.3
11.	Khokhra to Dadia	29.15	12.6	237.6	±24.6
12.	Khokhra to Dadia	22.6	22.6	858.6	±45.2
13.	Khokhra to Dadia	37.8	15.4	292.6	±30.9
National Park					
14.	Khokhra to Batheshwar	58	12	104.8	±29.7
15.	Khokhra to Batheshwar	28.8	33.9	884.8	±67.1
16.	Khokhra to Batheshwar	101.5	30.1	209.9	±59.08

Table 95. Individual transect densities for Chital by Fourier series estimator (Grouped and truncated data). Vehicle count, Summer 1989.

Sl. No.	Transect	Density	S.E.	% Coeff. of Var.	95% C.L.
Sanctuary West					
1.	Khokhora to Munda Chowk	115.1	29.7	210.9	±59.5
2.	Khokhra to Batheshwar	11.9	14.5	708.7	±28.07
3.	Khokhra to Munda Chowk	53.8	53.8	19.7	±38.4
4.	Khokhra to Munda Chowk	75.7	26.9	255.6	±53.6
5.	Khokhra to Munda Chowk	120.32	31.02	248.1	±62.98
6.	Khokhra to Batheshwar	57.2	19.25	188.6	±38.5
7.	Khokhra to Batheshwar	148.7	39.6	234.9	±77.8
8.	Khokhra to Batheshwar	63.75	60.7	714.7	±120
9.	Khokhra to Batheshwar	115.2	34.4	238.4	±67.2
10.	Kankai Naka to Chodavadi	30.8	11.3	245.2	±22.1
11.	Gola turnoff to Kalipat	21.8	12.4	299	±25.4
12.	Chodavadi to Kamleshwar Patia	37.06	10.4	95.5	±20.4
National Park					
13.	Kankai Naka to Kankai	55.4	28.06	314.7	±55.5
14.	Ratanguna to Pilipat	14.4	14.4	668.6	±28.9
15.	Kankai Naka to Kankai	39.6	24.4	443.5	±47.5
16.	Kankai Naka to Kankai	18.5	12	327.5	±24.5
17.	Kankai Naka to Kankai	38.4	17.4	273.6	±34.2
18.	Kankai Naka to Kankai	62.16	17.05	115.08	±33.6
19.	Kankai Naka to Kankai	20.8	10.7	262.6	±20.5

20.Kankai Naka to Kankai	33.06	18.8	326.04	±37.62
21.Kankai Naka to Kankai	41.8	16.4	209.8	±32.8
22. Kankai Naka to Kankai	110.7	35.1	171.1	±69.1
<u>Sanctuary East</u>				
23. Bhimchas to Rajsthali	11.3	14.04	663.1	±28.08
24. Bhimchas to Bhanej	68.8	38.4	672	±77.04
25. Bhimchas to Rajsthali	95.2	39.9	399.9	±79.1
26. Bhanej to Bhimchas	120.6	34.8	250.5	±67.8
27. Bhimchas to Bhanej	87.4	23.6	177.2	±47.3
28. Bhimchas to Chikalkuba	46.9	17.8	206.2	±35.6
29. Bhimchas to Rajsthali	67.7	27.2	176.8	±53.6
30. Bhimchas to Chikalkuba	17.4	15.08	515.6	±30.1

APPENDIX - III

Table 96. % Frequency of food plant in Chital diet in 1988.

Plant species	Winter n=202	Summer n=163	Monsoon n=128	P-Monsoon n=43
Acacia nilotica	20.7	34.3	8.5	--
Acacia leucophloea	2.9	--	1.5	--
Aegle marmelos	0.99	--	0.68	--
Agave ingens	--	0.61	--	--
Asparagus	--	1.2	--	--
Bauhinia racemosa	1.4	1.2	2.3	--
Balanites aegyptica	2.4	3.06	--	--
Butea monosperma	0.99	0.61	--	--
Barleria prionitis	1.9	1.8	3.1	--
Capparis sepiaria	8.9	3.06	--	--
Carissa opaca	3.9	1.2	0.68	--
Combretum roxburgii	1.9	--	1.5	2.3
Cassia tora	0.49	--	0.78	--
Dichrostachys cineria	2.9	2.4	2.3	--
Ehretia laevis	--	1.2	--	--
Ficus religiosa	0.61	--	--	--
Flaucortia indica	0.49	1.2	0.68	--
Grewia tiliaefolia	0.99	--	--	--
Helicteres isora	4.9	5.5	1.5	--
Impatience balsemina	--	--	1.2	--
Ixora arborea	0.99	--	--	--

Morinda tinctoria	--	1.8	--	--
Securinega leucopyros	--	--	2.3	--
Tamarindus indica	--	--	0.78	--
Tectona grandis	0.49	1.2	--	--
Wrightia tinctoria	0.49	0.61	0.78	--
Zizyphus oenoplea	4.4	1.2	0.68	--
Zizyphus mauritiana	16.3	6.7	--	--
Zizyphus numularia	5.9	--	--	--
Zizyphus xylopyros	2.4	--	--	--
Grass	11.3	30.06	61.7	97.6

Table 97. % Frequency of food plant in Sambar diet in 1988.

Plant specis	Winter ----------- n=107	Summer ----------- n=127	Monsoon ------------ n=13
Acacia nilotica	--	4.7	--
Acacia leucophloea	0.93	--	--
Acacia catechu	0.93	--	--
Bauhinia racemosa	1.8	4.7	--
Bombax ceiba	0.93	--	--
Capparis sepiaria	7.4	--	--
Carissa opaca	1.8	1.5	--
Combretum roxbergii	--	3.9	--
Dichrostachys cineria	0.93	--	--
Emblica officinalis	2.8	--	--
Ficus religliosa	--	3.9	7.6
Helicteres isora	7.4	17.3	--
Mitragyna parvifolia	0.93	3.9	--
Morinda tinctoria	--	3.9	--
Neurocanthes	--	--	--
Rendia dumetorum	18.69	9.4	--
Tectona grandis	16.8	20.4	--
Wrightia tinctoria	33.6	17.3	--
Zizyphus oenoplea	0.93	--	--
Zizyphus mauritiana	--	3.9	--
Grass	--	4.7	92.3

Table 98. % Frequency of food plants in Nilgai diet in 1988.

Plant specis	Winter n=63	Summer n=59	Monsoon n=52
Acacia nilotica	4.7	10.1	--
Acacia catechu	1.5	10.1	--
Acacia leucophloea	34.9	27.1	--
Butea monosperma	19.04	25.4	7.6
Bauhinia racemosa	1.5	--	--
Balanites aegyptica	1.5	--	--
Morinda tinctoria	--	13.5	--
Rendia dumetorum	--	--	9.6
Terminalia crenulata	1.5	--	--
Tectona grandis	3.1	--	--
Wrightia tinctoria	6.3	--	19.2
Zizyphus oenoplea	3.1	--	--
Zizyphus mauritiana	9.5	10.1	7.6
Zizyphus xylopyros	4.7	--	--
Grass	6.3	--	44.2

Table 99. % Frequency of food plants in Chital diet in 1987.

Plant species	Winter n=60	Summer n=48	Monsoon n=49	P-Monsoon n=37
Acacia catechu	--	2.08	--	--
Acacia nilotica	6.6	6.25	2.04	8.1
Acacia leucophloea	1	--	--	--
Aegle marmelos	--	--	--	2.7
Bauhinia racemosa	1.6	4.1	--	2.7
Balanites aegyptica	1.6	--	--	--
Capparis sepiaria	5	2.08	--	2.7
Carissa opaca	8.3	4.1	--	--
Barlaria prionitis	--	--	--	5.4
Butea monosperma	--	2.08	--	--
Dichrostachys cineria	--	--	2.04	2.7
Diospyros melonoxylon	--	--	--	--
Flaucortia indica	1.6	--	--	--
Grewia tiliaefolia	--	--	--	2.7
Holarrhena antidysentrica	--	--	2.04	--
Holoptelia integrifolia	--	2.08	--	--
Helicteres isora	1.6	--	--	2.7
Tectona grandis	13.3	4.1	--	--
Wrightia tinctoria	1.6	--	--	--
Zizyphus mauritiana	3.3	2.08	--	--
Zizyphus oenoplea	--	--	2.04	2.7
Grass	55	70.8	91.8	67.5